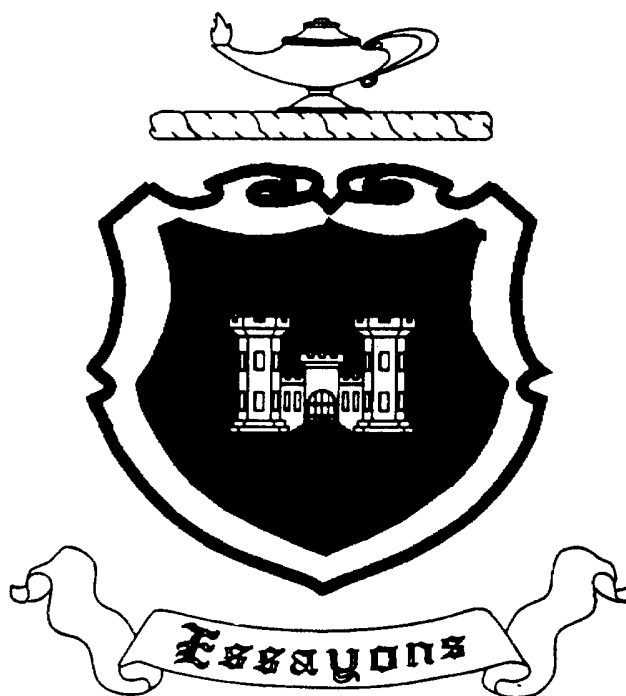


## CARPENTRY II



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## **CARPENTRY II**

Subcourse EN5156

### **EDITION B**

United States Army Engineer School  
Fort Leonard Wood, Missouri 65473

6 Credit Hours

Edition Date: November 1995

### **SUBCOURSE OVERVIEW**

Carpentry is the art or science of measuring, cutting, fitting, and assembling wood and other materials to construct buildings or other structures. Many people associate carpenters with wood and other building materials and tools. They assume carpenters build only homes and other relatively small structures. Of course, this is not true. Carpenters work not only with wood but also with metals, plastic, and other synthetic materials. The carpentry trade includes skills required to construct buildings, bridges, docks, and wharf. Work must be accomplished in a manner consistent with environmental laws and regulations

There are no prerequisites for this subcourse.

This subcourse reflects current doctrine when this subcourse was prepared. In your own work, always refer to the latest publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

#### **TERMINAL LEARNING OBJECTIVE:**

The Carpentry II subcourse, (Carpentry/Masonry Specialist, Military Occupational Specialty (MOS) 51B, Skill Levels 1 and 2), will provide you with enough knowledge to construct floor systems, stairs, wall systems (including the installation of windows and door), and roof systems of wooden structures. This subcourse is presented in three lessons. At the end of these lessons, you will be able to take a set of construction drawings and construct a wood-frame building

**ACTION:** You will describe the construction of floor, wall, stair, and roof systems and the installation of doors and windows.

- CONDITION:** You will be given the material in this subcourse and an Army Correspondence Course Program (ACCP) examination response sheet.
- STANDARD:** To demonstrate competency of this task, you must achieve a minimum of 70 percent on this subcourse.

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## LESSON 1

### FLOOR CONSTRUCTION

Critical Task: 051-236-1141

### OVERVIEW

#### LESSON DESCRIPTION:

In this lesson you will learn how to perform one task-construct a floor.

#### TERMINAL LEARNING OBJECTIVE:

ACTION: You will describe the construction of a floor system.

CONDITION: You will be given the material contained in this lesson.

STANDARD: You will correctly answer the practice exercise questions at the end of this lesson.

REFERENCES: The material contained in this lesson was derived from FM 5-426.

### INTRODUCTION

After the foundation is in place, you are ready to start constructing the framework for the floor system.

### PART A - FLOOR FRAMING

**1-1. Types of Sills.** *Sills* are the horizontal timbers of a building which either rest up the masonry foundations or, in the absence of such, form the foundations. The sill is the foundation that supports all of the building above it. It is the first part of the building to be set in place and rest directly on the foundation, posts, or the ground. Sills are joined at the corners and spliced when necessary. The type of sill used depends on the type of construction used in the frame.

a. Box Sills. Figure 1-1, page 1-2, shows box sills. Box sills are often used with the common style of platform framing (either with or without a sill plate). With this type of ill, the part that lies on the foundation wall or ground is called the *sill plate*. The sill is laid edgewise on the outside edge of the sill plate.

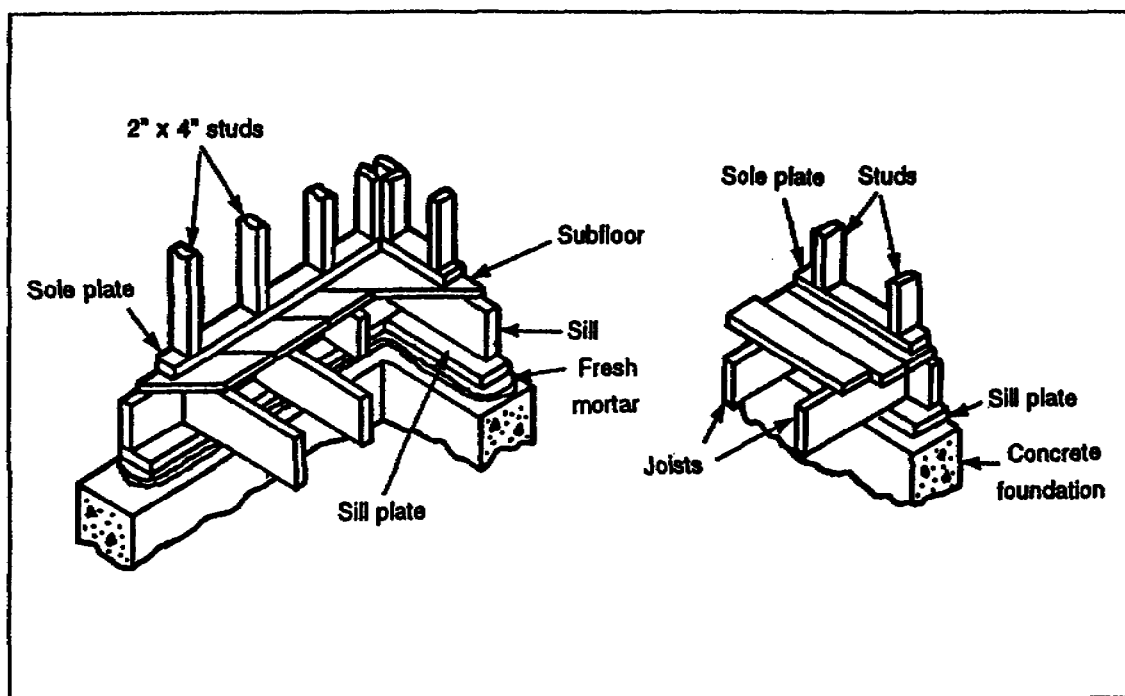


Figure 1-1. Box sills

b. T-Sills. There are two types of T-sill construction—sills commonly used in dry, warm climates (see Figure 1-2) and sills used in colder climates (see Figure 1-3). Although these T-sill constructions are similar, notice that in Figure 1-2 the joists are nailed to the studs and sole plates. In Figure 1-3 the joists are nailed to the studs and sills and headers are used between the floor joists.

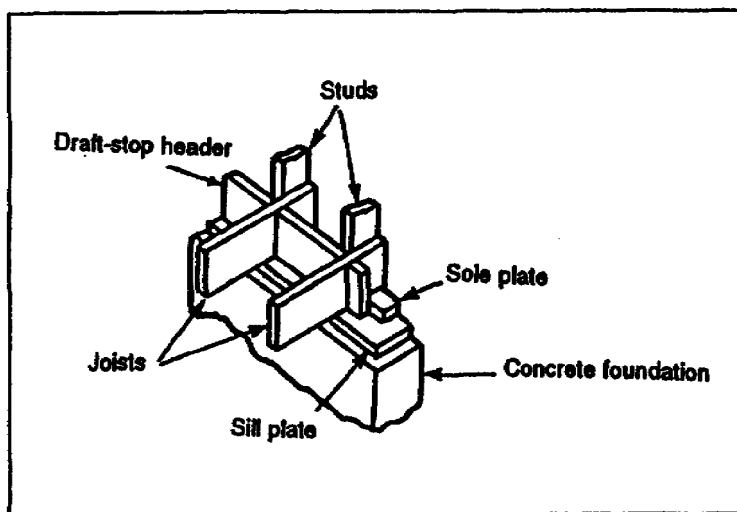
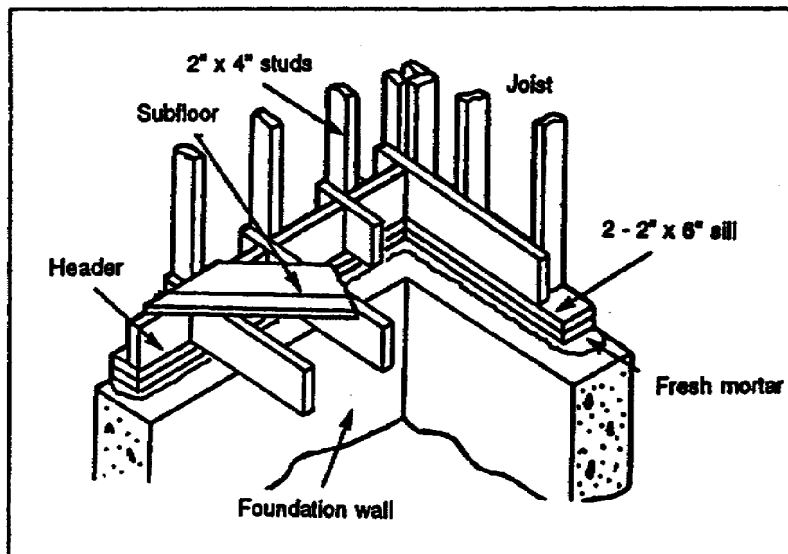
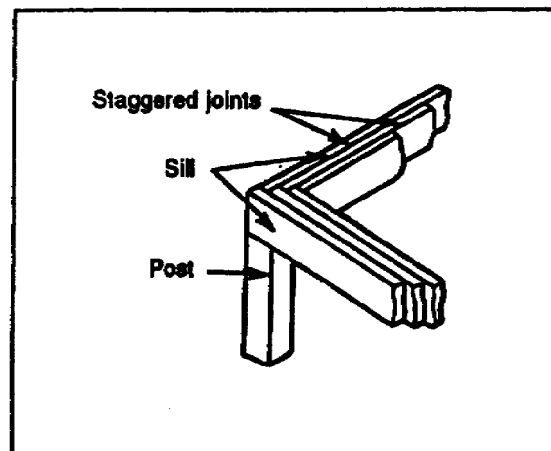


Figure 1-2. Dry-climate T-sill



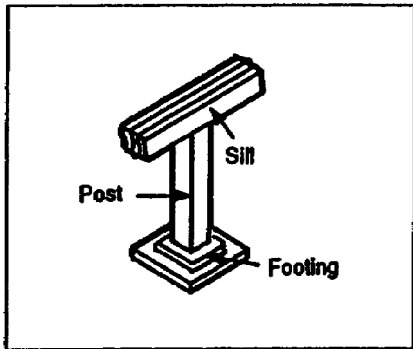
**Figure 1-3. Cold-climate T-sill**

c. Built-Up Sills. Joints are stagger where built-up sills are used. Notice in Figure 1-4 how the built-up sill corner joints are made. Heavier sills are used if posts are used in the foundation. Sills are single heavy timbers or built-up of two or more pieces of timber (see Figure 1-5, page 1-4). Where heavy timbers are used, the joints should be placed over the post (see Figure 1-6, page 1-4).

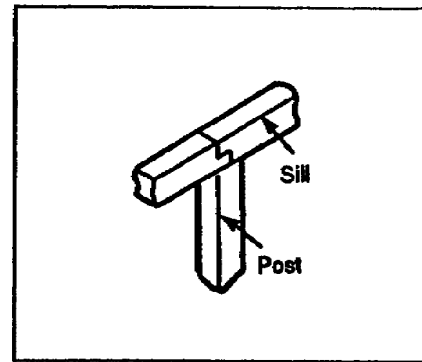


**Figure 1-4. Built-up sills**





**Figure 1-5. Braced framing sill**

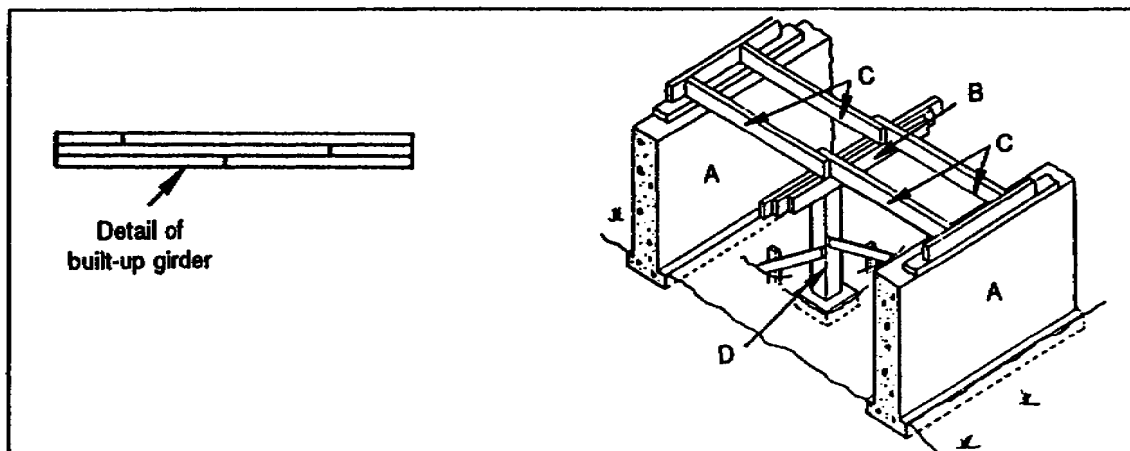


**Figure 1-6. Heavy timber sill**

**1-2. Types of Girders.** A *girder* is a large horizontal member used to support joists or beams. A girder is made of several beams nailed together with 16d (sixteen penny) common nails, solid wood, steel, reinforced concrete, or a combination of these materials. Girders carry a very large proportion of the weight of a building. They must be well-designed, rigid, and properly supported at the foundation walls and on the columns. Girders must be installed so that they support the joists properly. The ends of the wood girders should be at least 4 inches on the posts.

a. Built-up Girder. The built-up girder is commonly used in house construction. It is generally made of three boards nailed together with 16d common nails. Figure 1-7 shows a built-up girder, walls, joists, and columns.

- A shows two outside masonry walls.
- B shows the built-up girder.
- C shows the floor joists.
- D shows the support columns that support the girder.



**Figure 1-7. Built-up girder**



b. Girder with Ledger Board. Use a girder with a ledger board when vertical space is limited and where more headroom is needed (see Figure 1-8).

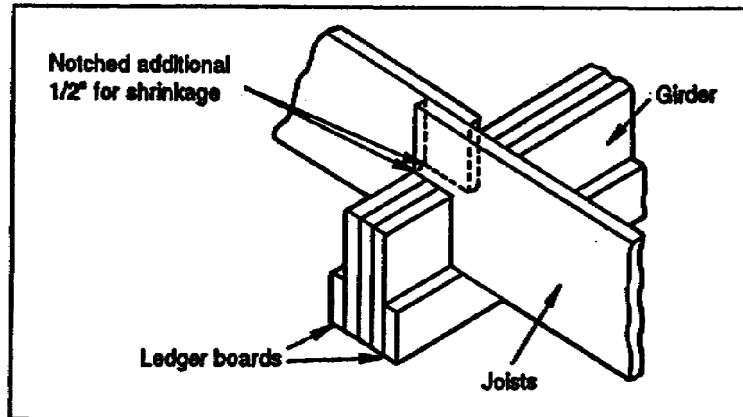


Figure 1-8. Girder with ledger board

c. Joist Hangers. A girder with joist hangers is used where there is little headroom or where the joists must carry an extremely heavy load (see Figure 1-9).

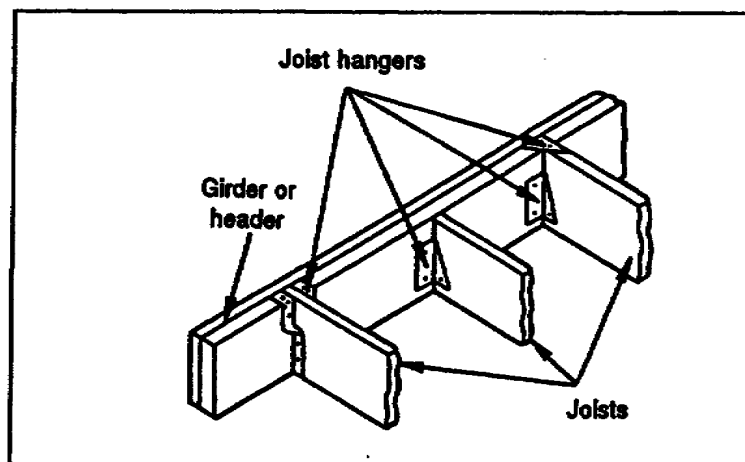


Figure 1-9. Joist hangers

**1-3. Girder Size Requirement.** A girder should be large enough to support the load. The carpenter should understand the effect of length, width, and depth of the wood girder. The principles which govern the size of a girder are--

- The distance between girder posts.
- The girder load area.
- The total floor load per square foot on the girder.

- The load per linear foot on the girder.
- The total load on the girder.
- The material to be used.

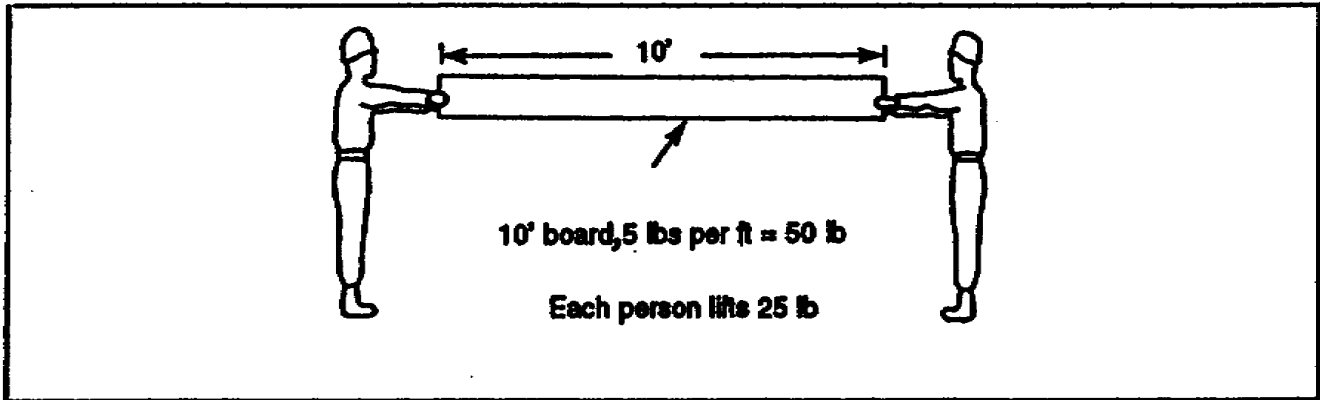
**1-4. Depth.** When the depth of a girder is doubled, the safe load is increased four times. For example, a girder that is 3 inches wide and 12 inches deep will carry four times as much weight as a girder 3 inches wide and 6 inches deep. To obtain greater carrying capacity, it is better to increase the depth than to increase the width of the girder. The sizes of built-up wood girders for various loads and spans may be determined by using Table 1-1.

**Table 1-1. Sizes of built-up wood girders**

Load Per Linear Foot of Girder	Length of Span (feet)				
	6	7	8	9	10
Nominal Size of Girder Required (Inches)					
750	6 x 8	6 x 8	6 x 8	6 x 10	6 x 10
900	6 x 8	6 x 8	6 x 8	6 x 10	8 x 10
1,050	6 x 8	6 x 10	8 x 10	8 x 10	8 x 12
1,200	6 x 10	8 x 10	8 x 10	8 x 10	8 x 12
1,350	6 x 10	8 x 10	8 x 10	8 x 12	10 x 12
1,500	8 x 10	8 x 10	8 x 12	10 x 12	10 x 12
1,650	8 x 10	8 x 12	10 x 12	10 x 12	10 x 14
1,800	8 x 10	8 x 12	10 x 12	10 x 12	10 x 14
1,950	8 x 12	10 x 12	10 x 12	10 x 14	12 x 14
2,100	8 x 12	10 x 12	10 x 14	12 x 14	12 x 14
2,250	10 x 12	10 x 12	10 x 14	12 x 14	12 x 14
2,400	10 x 12	10 x 14	10 x 14	12 x 14	
2,550	10 x 12	10 x 14	12 x 14	12 x 14	
2,700	10 x 12	10 x 14	12 x 14		
2,850	10 x 14	12 x 14	12 x 14		
3,000	10 x 14	12 x 14			
3,150	10 x 14	12 x 14			
3,300	12 x 14	12 x 14			
<b>NOTES:</b> 1. The 6-inch girder is figured as being made with three pieces 2-inch dressed to 1 3/4-inch thickness. 2. The 8-inch girder is figured as being made with four pieces 2-inch dressed to 1 3/4-inch thickness. 3. The 10-inch girder is figured as being made with five pieces 2-inch dressed to 1 3/4-inch thickness. 4. The 12-inch girder is figured as being made with six pieces 2-inch dressed to 1 3/4-inch thickness. 5. For solid girders, multiply the above loads by 1.130 when a 6-inch girder is used; 1.150 when an 8-inch girder is used; 1.170 when a 10-inch girder is used; and 1.180 when a 12-inch girder is used.					

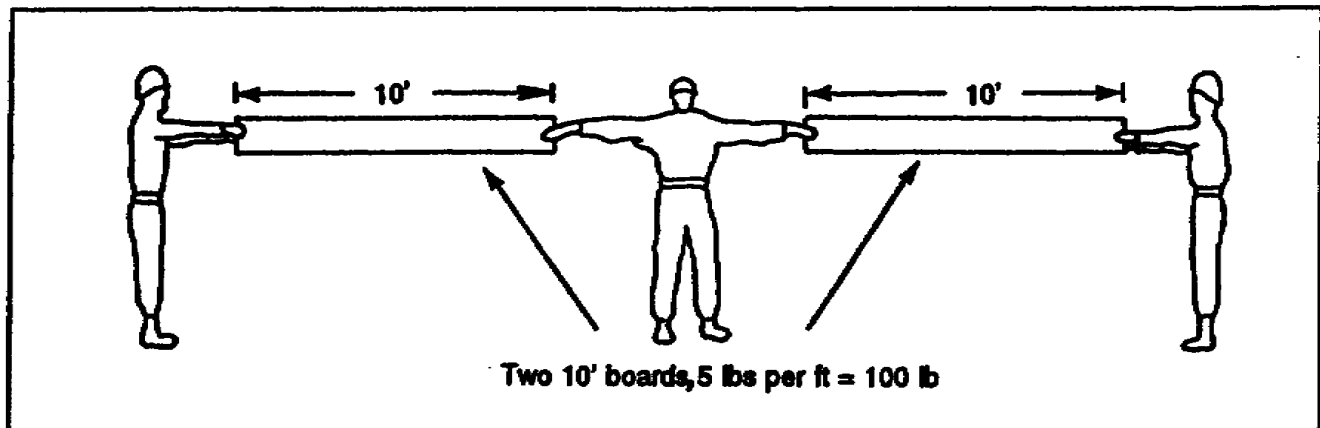
**1-5. Load Area.** Both the foundation walls and the girder carry the load area of a building. Because the ends of each joist rest on the girder, there is more weight on the girder than on either of the wall.

*Example 1.* Before considering the load on the girder, consider the weight of a single joist. Suppose that a 10-ft board weighing 5 pounds per foot is led by two men. If the men are at opposite ends of the plank, they would each be supporting 25 pounds (see Figure 10).



**Figure 1-10. Example of weight on a single joist**

*Example 2.* Now assume that one of these men lifts the end of another 10-ft board with the same weight as the first one, and a third man lifts the opposite end. The two men on the outside are each supporting half the weight of one plank, or 25 pounds apiece, but the man in the center is supporting one half of each of the two boards, or a total of 50 pounds (see Figure 1-11).



**Figure 1-11. Example of weight on a girder**

The two men on the outside represent the foundation walls. The center man represents the girder. The girder carries half of the weight and the other half is equally divided between the outside walls. However the girder may not always be located halfway between the outer walls.

*Example 3.* Imagine the same three men lifting two planks that weigh 5 pounds per foot. One of the planks is 8 feet long and the other is 12 feet long. The total length of these two planks is the same as before. The weight per foot is the same, so the total weight in both cases is 100 pounds.

One of the outside men is supporting half of the 8-foot plank, or 20 pounds. The man on the opposite outside end is supporting half of the 12-foot plank, or 30 pounds. The man in the center is supporting one half of each plank, or a total of 50 pounds. This is the same total weight he was lifting before. It is important to remember that a girder carries the weight of the floor on each side to the midpoint of the joists which rest upon it.

**1-6. Floor Load.** After the girder load area is known, the total floor load per square foot must be determined for safety purposes. Both dead and live loads must be considered.

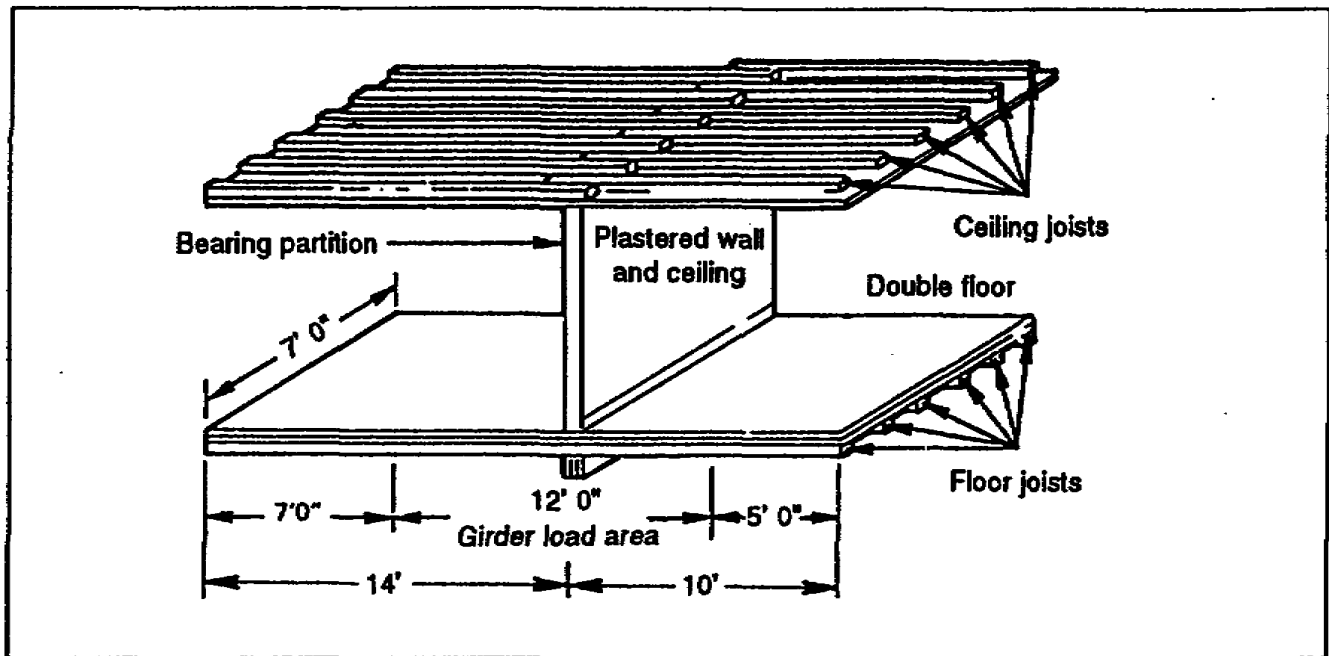
a. **Dead Load.** A buildings structure weight is called the *dead load*. The dead load per square foot of floor area is carried directly or indirectly to the girder by bearing partitions. Dead load varies according to the method of construction and the building height. The structural parts included in the dead load are--

- Floor joists for all floor levels.
- Flooring materials, including the attic if it is floored.
- Bearing partitions.
- Attic partitions.
- Attic joists for the top floor.
- Ceiling lath and plaster, including the basement ceiling if it is plastered.

b. **Total Dead Load.** For a building of light frame construction similar to an ordinary frame house, the dead-load allowance per square foot of all structural parts must be added together to determine the total dead load. The allowance for an average subfloor, finished floor, and joist without basement plaster should be 10 pounds per square foot. If the basement ceiling is plastered, an additional 10 pounds per square foot should be allowed. If the attic is unfloored, a load allowance of 20 pounds must be made for ceiling plaster and joists when girders or bearing partitions support the first-floor partition. If the attic is floored and used for storage, an additional 10 pounds per square foot should be allowed.

c. **Live Load.** The weight of furniture, persons, and other movable loads, not actually a part of the building but still carried by the girder, is called the *live load*. The live load per square foot will vary according to the use of the building and local weather conditions. Snow on the roof is considered part of the live load. The allowance for the live load on the floors used for living purposes is usually 30 pounds per square foot. If the attic is floored and used for light storage, an additional 20 pounds per square foot should be allowed. The allowance per square foot for live loads is usually governed by local building specifications and regulations.

d. **Load Per Linear Foot.** When the total load per square foot of floor area is known, the load per linear foot on the girder can easily be figured. Assume that the girder load area of the building shown in Figure 1-12 is sliced into 1-foot lengths across the girder. Each slice represents the weight supported by 1 foot of the girder. If the slice is divided into 1-foot units, each unit will represent 1 square foot of the total floor area. The load per linear foot of a girder is determined by multiplying the number of units, 12, by the total load per square foot, 70 pounds. This gives you 840 pounds per linear foot on the girder ( $12 \times 70 = 840$  pounds). Now you can take the 840 pounds per load per linear foot of girder and use Table 1-1, page 1-6, to determine the girder size. If your number is not on the table, round up.



**Figure 1-12. Girder load per linear foot**

e. **Total Floor Load.** Note in Figure 1-12 that the girder is off center. Remember that half of the load is supported by the girder and half is supported by the foundation walls. Therefore, the joist length to be supported on one side of the girder is 7 feet (half of 14 feet), and the other side is 5 feet (half of 10 feet) for a total distance of 12 feet across the load area. Since each slice is 1 foot wide, it has a total floor area of 12 square feet. Assume that the total floor load for each square foot is 70 pounds. Multiply the length times the width (7 feet x 12 feet) to get the total square feet supported by the girder (7 feet x 12 feet = 84 square feet).

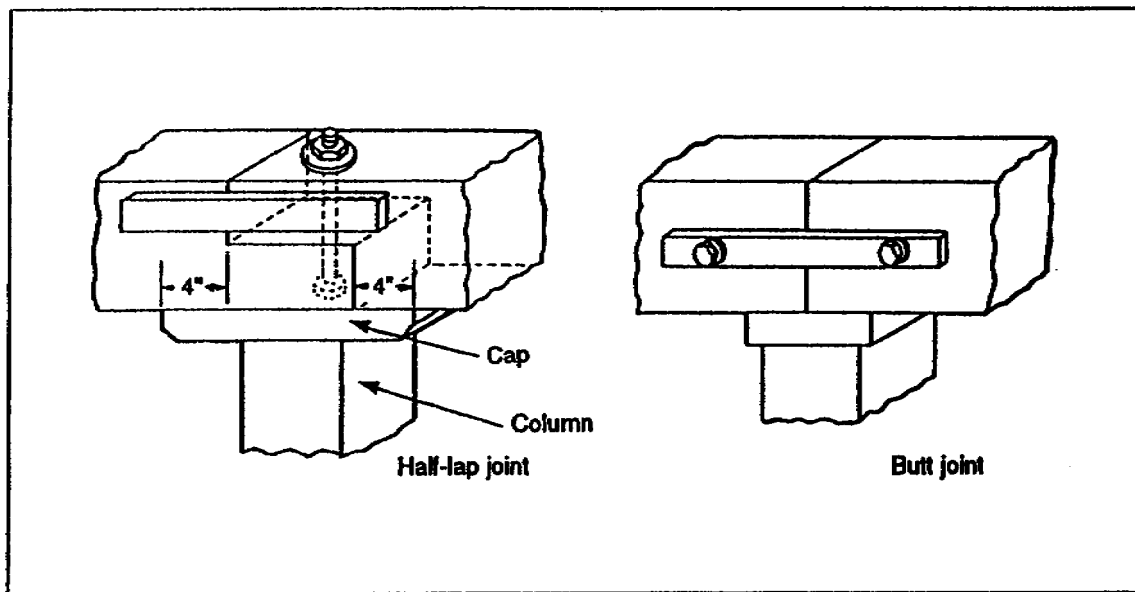
**1-7. Girder Material.** Wooden girders are more common than steel girders in small frame buildings. Solid timbers may be used, or girders may be built up by using two or more 2-inch planks. Built-up girders warp less easily than solid wooden girders and are less likely to decay in the center.

a. **Choice of Material.** Regardless of whether the girder is built-up or solid, it should be of well-seasoned material. For a specific total girder load and span, the size of the girder will vary according to the kinds of wood used, since some woods are stronger than others.

b. Use of Nails. When built-up girders are used, the pieces should be securely nailed together to prevent individual buckling. A two-piece girder of 2-inch lumber should be nailed on both sides with 16d common nails. The nails should be located near the bottom, spaced approximately 2 feet apart near the ends and 1 foot apart in the center. A three-piece girder should be nailed in the same way. The nailing pattern should be square across the end of the board (1 1/2 inches from each end) and then diagonal every 16 inches.

**1-8. Girder Splices.** To make a built-up girder, select straight lumber free from knots and other defects. The stock should be long enough so that no more than one joint will occur over the span between footings. The joints in the beam should be staggered, taking care to square the planks at each joint and butt them tightly together.

a. Half-Lap Joint Sometimes a half-lap joint is used to join solid beams. In this case, place the beam on one edge so the annual rings run from top to bottom. The lines for the half-lap joint are then laid out (see Figure 1-13). Cuts are made along these lines, then checked with a steel square to assure a matching joint. Repeat this process on the other beam.



**Figure 1-13. Girder splices**

b. Temporary Strap. Tack a temporary strap across the joint to hold it tightly together. Drill a hole the joint with a bit about 1/16 inch larger than the bolt to be used, and fasten the joint with a bolt, a washer, and a nut.

c. Strapped Joint. When a strapped butt joint is used to join solid beams, the ends of the beams should be cut square. The straps, which are generally 18 inches long, are bolted to each side of the beams.



**1-9. Girder Supports.** When small houses are built without an architect, the carpenter must know the principles that determine the proper size of girder supports.

a. Columns. A vertical member, designed to carry the live and dead loads placed upon it is called a *column* or a *post*. It can be made of wood, metal, or masonry. Wooden columns may be solid timbers or several wooden members nailed together with 16d or 20d common nails. Metal columns are made of heavy pipe, large steel angles, or I-beams.

b. Column Spacing. A good arrangement of the girder and supporting columns for a 24-foot by 40-foot building is shown in Figure 1-14. Column B will support one half of the girder load existing in the part the building lying between wall A and column C. Column C will support half of the girder load between columns B and D. Likewise, column D will share the girder loads equally with column C and wall E.

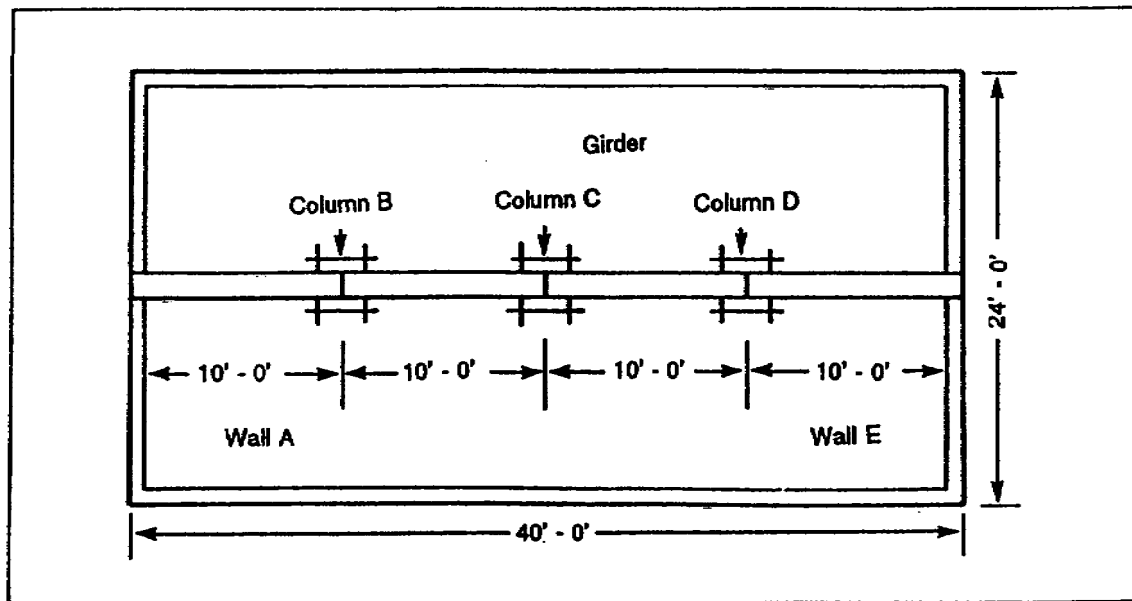
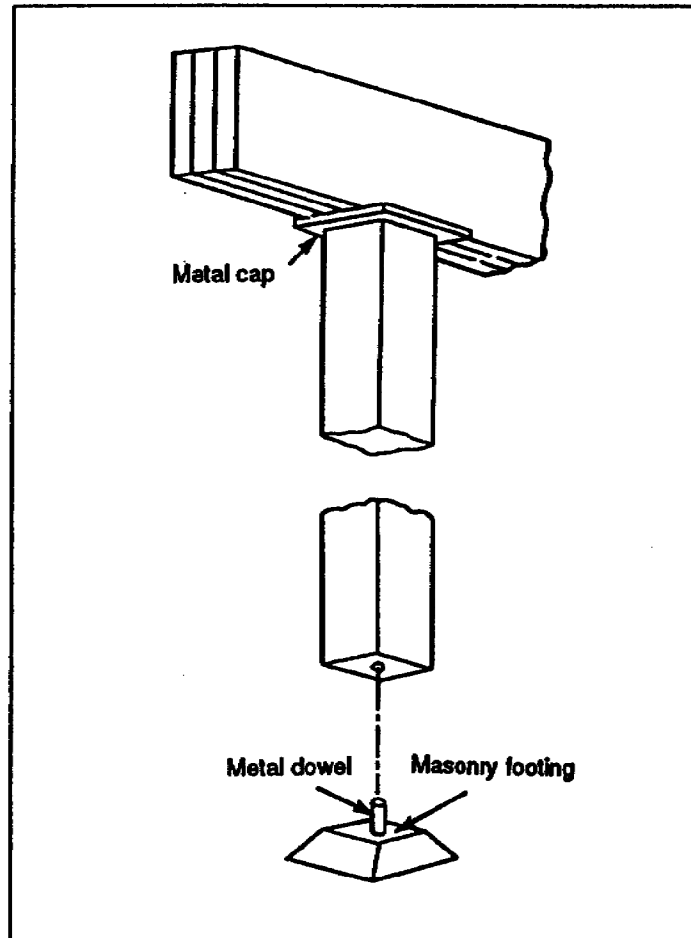


Figure 1-14. Girder and column spacing

**NOTE:** When locating columns which must support girders, avoid spans of more than 10 feet between columns. The farther apart columns are spaced, the heavier the girder must be to carry the joist over the span between the columns.

c. Bearing Plates and Footings. Regardless of the material used in a column, it must have some form of a bearing plate at the top and bottom. These plates distribute the load evenly across the column. Basement posts that support girders should be set on masonry footings. Columns should be securely fastened at the top to the load-bearing member and at the bottom to the footing on which they rest.

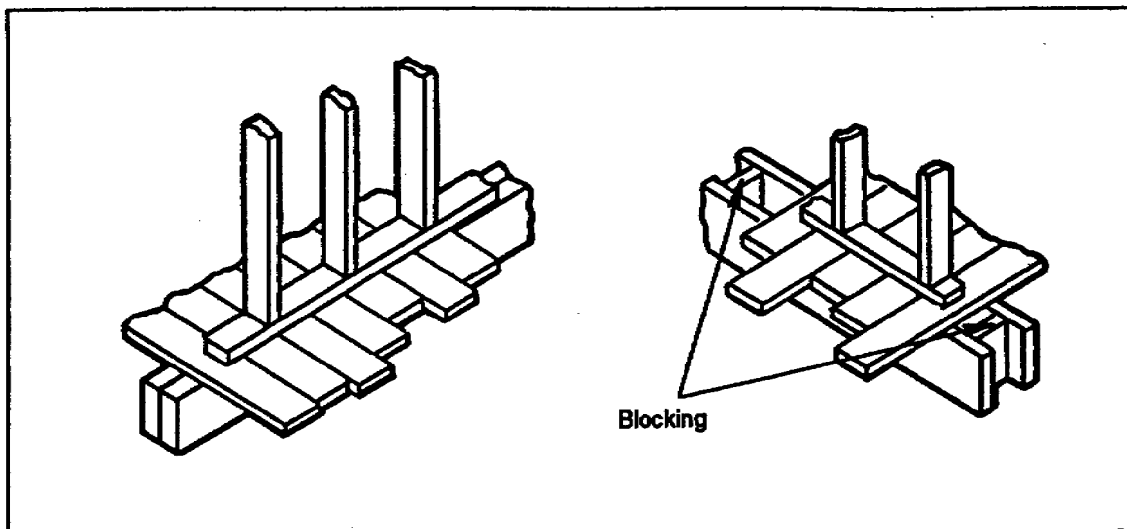
d. Column Fastening. Figure 1-15 shows a solid wooden column with a metal bearing cap drilled so that it can be fastened to the column and to the girder. The bottom of this type of column may be fastened to the masonry footings by a metal dowel. The dowel should be inserted in a hole drilled in the bottom of the column and in the masonry footing. The base is coated with asphalt at the drilling point to prevent rust or rot.



**Figure 1-15. Girder and column fastening**

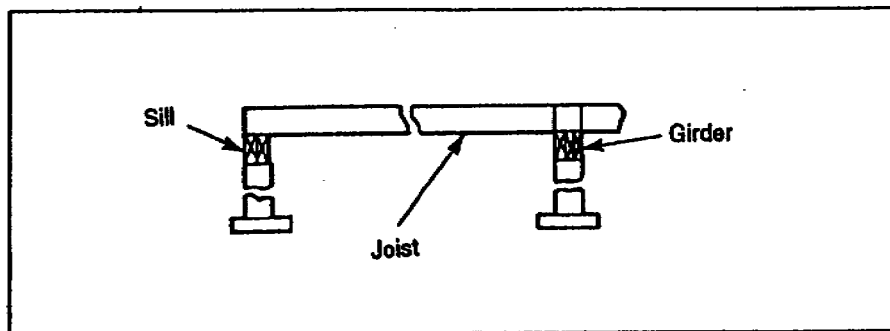
**1-10. Floor Joists.** *Joists* are wooden members, usually 2 or 3 inches thick, that make up the body of the floor frame. The flooring or subflooring is nailed to them.

a. **Joist Loads.** Joists usually carry a uniform load of materials and personnel. These are live loads. The weight of joists and floor is a dead load. Joists are spaced 16 or 24 inches on the center. Sometimes the spacing is 12 inches, but where such spacing is made necessary by the load, heavier joists should be used. In certain parts of the floor frame, to support heavily concentrated loads or a partition wall, it may be necessary to double the joists or to place two joists together (see Figure 1-16).



**Figure 1-16. Reinforced joists**

b. Joists and Sills. When joining joists to sills, be sure that the connection can hold the load that the joist will carry. A joist resting on the sill and girder is shown in Figure 1-17. This connection method is most commonly used because it provides the strongest possible joint. The method shown in Figure 1-18, page 1-14, a joist with ledger plates is used when it is not desirable to use joists on top of the sill. The ledger plate should be securely nailed to the sill and girder. If the joist must be notched, it should be securely nailed to the sill and girder. If the joist must be notched, it should not be notched over one third of its depth (to prevent splitting). Joists must be level when framed to girders. If the joist is not the same height as the girder, the joist must be notched (see Figure 1-19, page 1-14).



**Figure 1-17. Joist resting on sill**

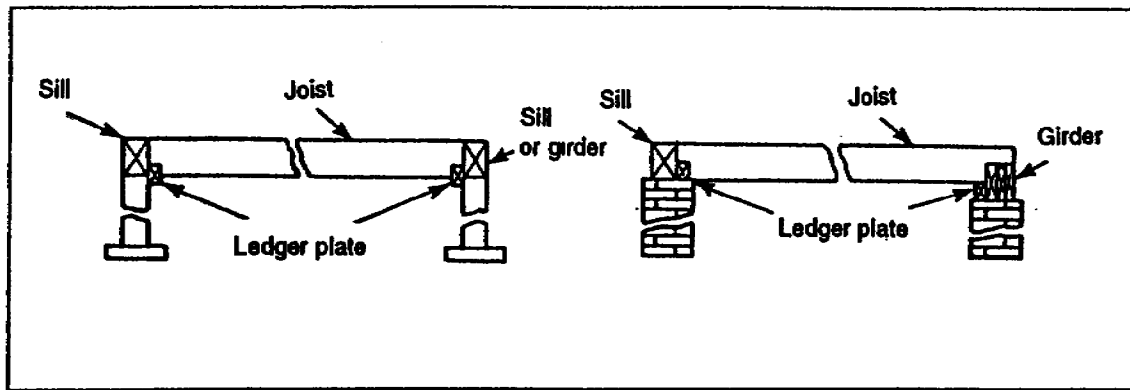


Figure 1-18. Joist with ledger plates

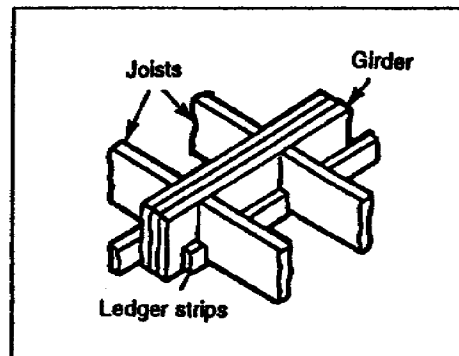


Figure 1-19. Joist connected to a girder

c. Joist Hangers. When it is desirable to have the joists and girders flush, the ends of the joists can be supported by joist hangers (see Figure 1-20). Joist hangers support joists at the girders. When joists are hung using joist hangers, the maximum headroom is obtained below the girder.

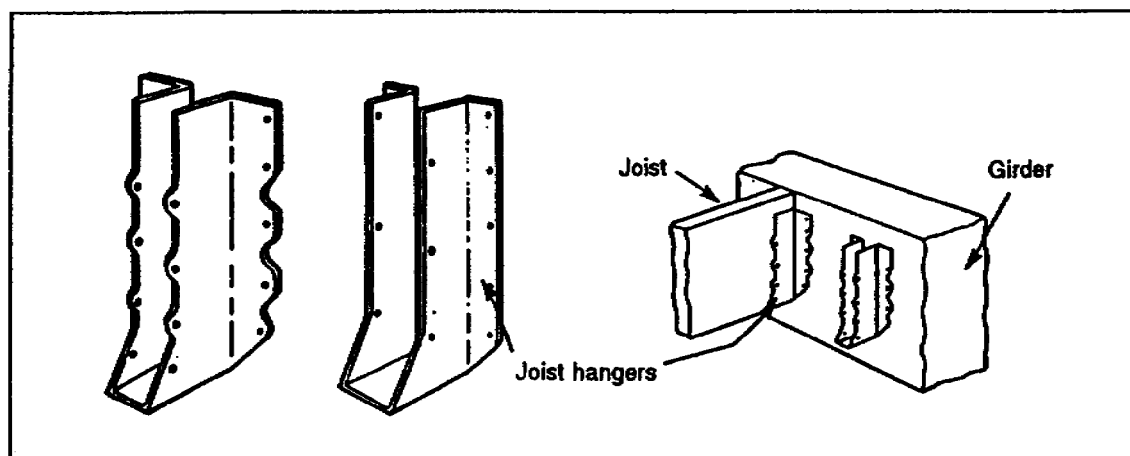
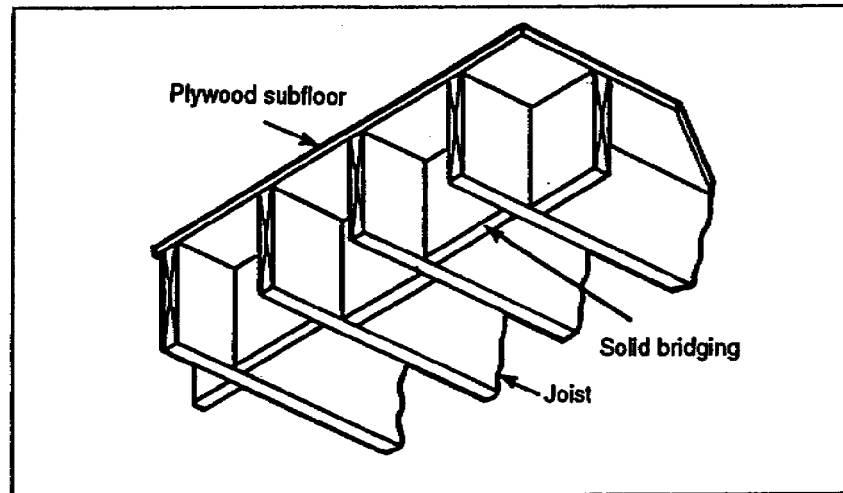


Figure 1-20. Joist hangers

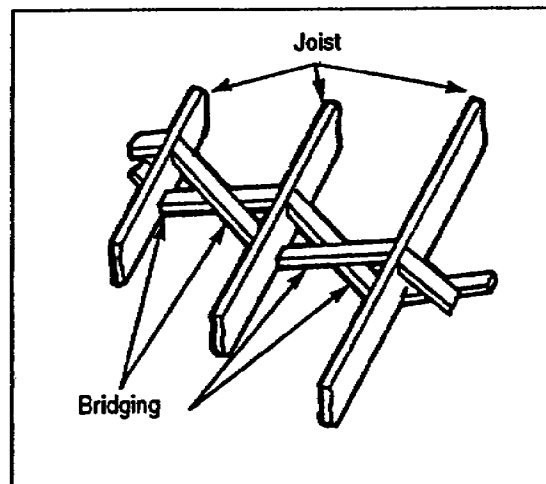
**1-11. Bridging.** When the joists are used over a long span, they tend to sway from side to side. Therefore, bridging is installed. Floor frames are bridged for stiffening and to prevent unequal deflection of the joists. Bridging enables an overloaded joist to receive some help from the joist on either side of it. A pattern for the bridging stock is obtained by placing a piece of material between the joist, then marking and sawing it. There are three types of bridging: solid, cross, and compression.

a. Solid. To provide maximum rigidity to the joist, use solid bridging. The bridging is offset to permit end nailing where possible (see Figure 1-21).



**Figure 1-21. Solid bridging**

b. Cross. Wood-cross bridging is used most often. It is cut to fit diagonally between joists (see Figure 1-22). Each piece is nailed to the top of each joist before the subfloor is placed. The bottoms are left free until the subfloor is laid. This permits the joists to adjust themselves to their final positions and keeps the bridging from pushing up the joists and causing an uneven floor.



**Figure 1-22. Cross bridging**

c. Compression. Use hammer blows to install compression bridging. Where the bridging is drilled, it is nailed in place (see Figure 1-23).

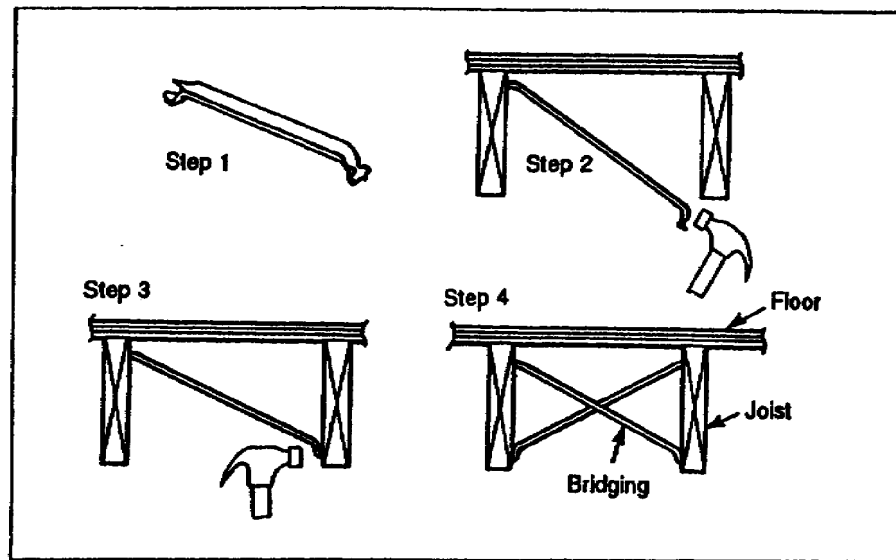
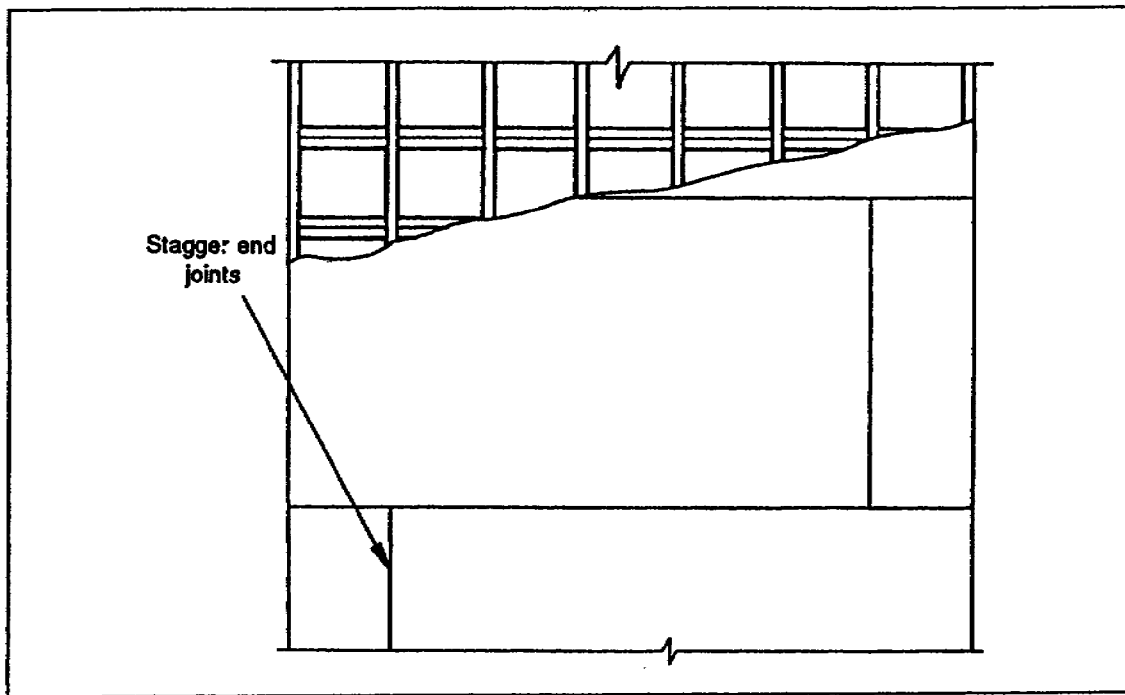


Figure 1-23. Installation of cross bridging

## PART B - SUBFLOORING

**1-12. Plywood Subflooring.** After the foundation and basic framework for the floor are completed, the subfloor can be installed. Material for constructing the subfloor can be either 1-inch or 2-inch material. Plywood is very satisfactory for subflooring because of the large sheets which can be installed rapidly. The thicknesses required are 1/2-, 5/8-, or 3/4-inch, depending on the joist spacing and the floor load requirement.

- Lay sheets with the face grain at a right angle to the joist when installing plywood.
- Lay the sheets so that the joints are placed over the joists.
- Arrange plywood so that the joints for the complete floor are staggered (see Figure 1-24).
- Glue and nail the plywood in place.



**Figure 1-24. Plywood subflooring**

**1-13. Diagonal Subflooring.** Lay diagonal subflooring on the joist framework and nail it in place (See Figure 1-25, page 1-18). Subfloor material can be either 1-inch or 2-inch material.

- Lay the subfloor before the walls are framed.
- Square the ends of the boards before nailing when laying the flooring.
- Place the ends of the boards before nailing when laying the flooring.
- Use at least three nails per joist for boards 8 inches wide or more.

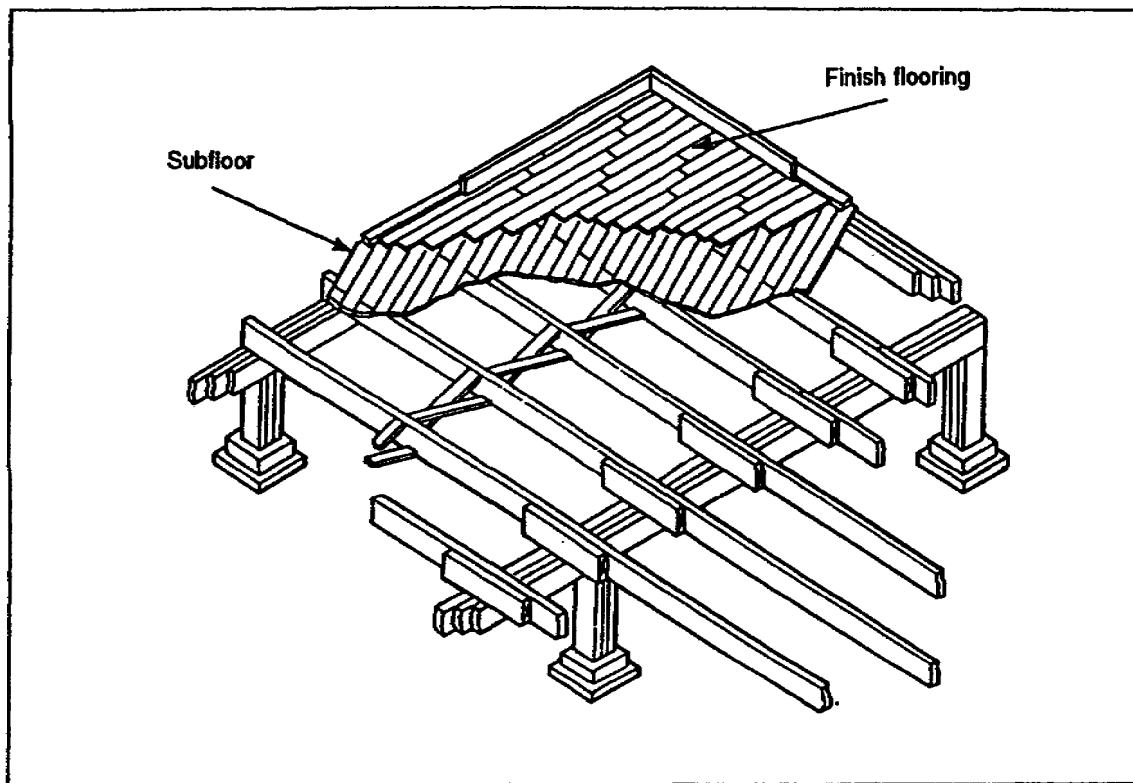


Figure 1-25. Diagonal subflooring

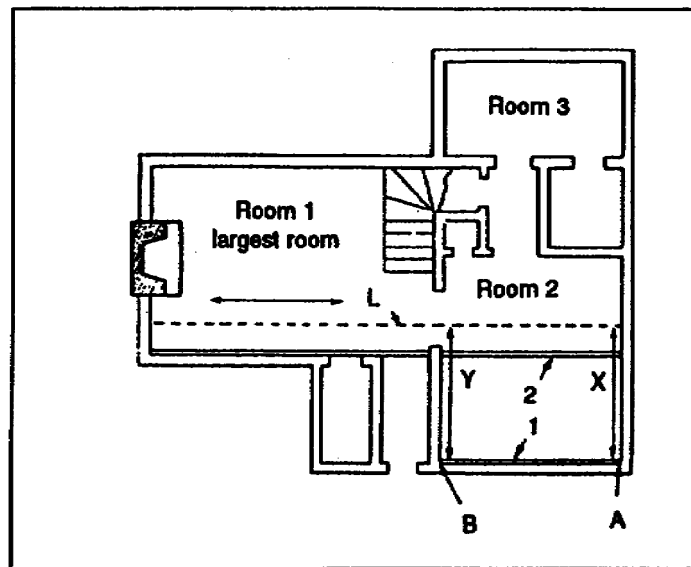
## PART C - FINISH FLOORING

**1-14. Prepare to Lay a Floor.** The finish flooring should be delivered to the job site in sufficient time to allow the carpenter to lay out the floor. This allows the flooring to adjust to the moisture and temperature conditions in the building. Fifteen-pound asphalt felt should be placed over the subfloor before installing the finish flooring. Before laying the floor, check the floor plans to determine which of the rooms is the largest and what its relationship is to the other rooms. If laying strip flooring, see if the flooring will extend from the largest room into the next room. If so, lay the flooring in the longest direction. Check the walls of the largest room to see if the opposite walls are parallel to each other. Snap a chalk line parallel along the longest wall to establish a straight line (called a *baseline*). This line should extend into the next room so the strip flooring will be continuous.

**1-15. Lay the Floor.** The following guidelines should be used when laying a floor:

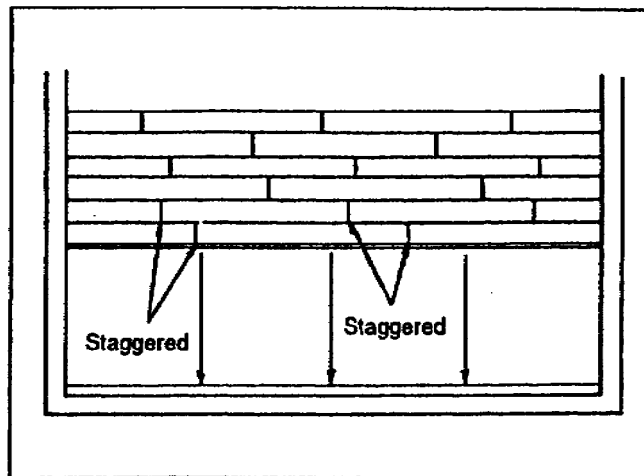
- a. Select a long straight piece of flooring for the first board. Place this piece of flooring in position with the grooved edge toward the wall (see Figure 1-26). Allow approximately 1/4 inch along the wall for expansion.



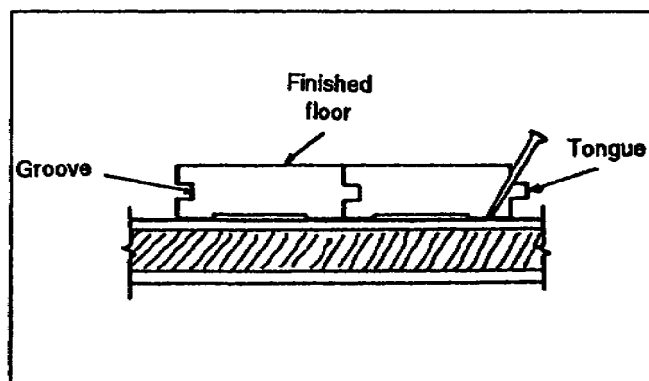


**Figure 1-26. Floor plan**

- b. Face nail the board at A with a finish nail, but do not drive the nail home.
- c. Measure the distance X from the face of the first board to the chalk line L.
- d. Transfer this distance to Y and set a nail at B. Now board 1 is parallel to the chalk line L and to the longest wall in the largest room.
- e. Use a straightedge to ensure that board 1 is straight. Then face nail the board every 12 inches. Nail as close to the wall as possible.
- f. Continue to cut, fit, and nail the flooring until the board marked 2 has been reached.
- g. Make sure the board joints are staggered (see Figure 1-27, page 1-20).
- h. Blind nail the rest of the tongue-and-groove flooring through the tongue at about 50 degrees to the floor. To draw up the tongue-and-groove flooring for nailing, use a short piece of tongue-and-groove lumber as a straightedge and a hammer to drive the flooring up tight (see Figure 1-28, page 1-20).

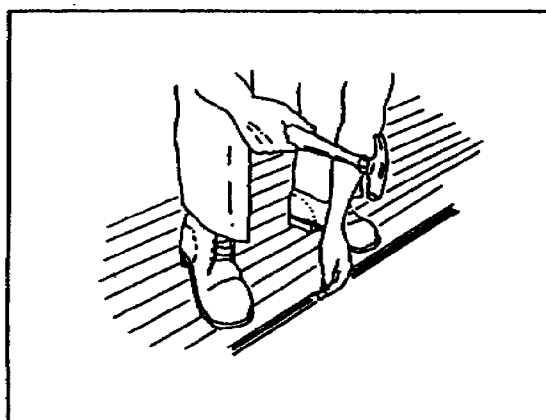


**Figure 1-27. Staggered board joints**



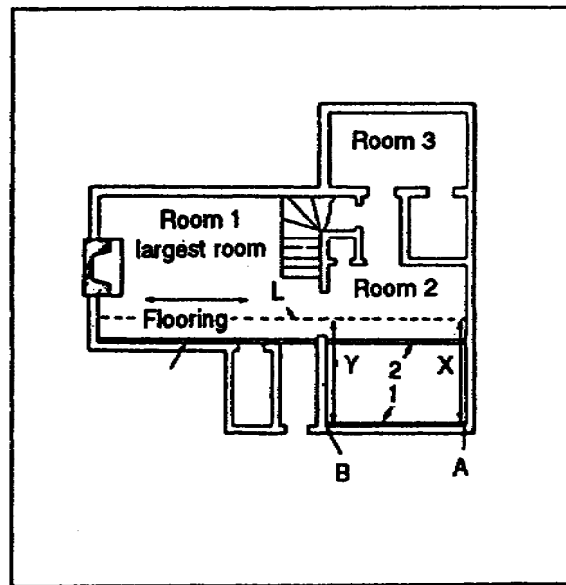
**Figure 1-28. Blind nailing**

- i. Stand on the board to be nailed when nailing the floor in place. This holds the strips of flooring in place (see Figure 1-29).



**Figure 1-29. Nailing floor in place**

j. Look at baseline L in Figure 1-30. When the finished floor has been laid up to line 2, the starter board 3 in the largest room should be laid. The front edge of this board should be the same distance from the chalk line L as the front edge of board 2. This ensures that the boards will come out evenly at the door opening, where the flooring passes from room 1 to room 2.



**Figure 1-30. Floor plan**

k. Continue laying the floor until you are within two or three boards from the opposite wall.

l. Now, cut the last few boards, open up the groove in the boards, place them in position, draw them tightly together, and surface nail them in place.

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## LESSON 1

### PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. When you have completed the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part which contains the portion involved.

1. Which part of the floor system for a frame building rests directly on the masonry foundation?
  - A. Sills
  - B. Joists
  - C. Solid bridging
  - D. Pier plates
2. What are the three types of sills used to construct a floor system?
  - A. Built-up, T, and girders
  - B. T, built-up, and box
  - C. Box, T, and plate
  - D. Plate, edge, and T
3. The load area of a building is carried by both the foundation and the--
  - A. Joists
  - B. Partitions
  - C. Joist hangers
  - D. Girder
4. Suppose you must increase the girder load capacity to four times greater than the existing girder (which is 3 inches wide and 6 inches deep). What size girder (in inches) would you install?
  - A. 3 x 8
  - B. 3 x 10
  - C. 3 x 12
  - D. 6 x 12

5. Refer to Table 1-1, page 1-6. You are required to determine the girder size for a specific building. There are 14 units of floor area, and the total load per square foot is 80 pounds. What size girder (in inches) is required?
- A. 6 x 8
  - B. 6 x 10
  - C. 8 x 10
  - D. 8 x 12
6. You know that floor joists are wooden members that make up the body of the floor frame and sometimes must be doubled. Why is it necessary to double a floor joist?
- A. Because heavily concentrated loads must be supported.
  - B. Because of the defective lumber you have to work with.
  - C. Because of the extra long spans between foundation walls.
  - D. Because of a weak floor.
7. What is the strongest method for installing floor joists?
- A. Joists resting upon sills and girders
  - B. Joists installed with ledger boards
  - C. Joists installed using metal hangers
  - D. Joists installed with metal hangers and 16d nails
8. Why is bridging used when constructing the floor system?
- A. To strengthen the weak parts of the subfloor.
  - B. To allow equal weight to be distributed across the girder.
  - C. To stiffen the floor frame.
  - D. To add strength to the joist hangers.
9. How is cross bridging installed in a floor system?
- A. The top of the cross bridging is nailed to the top of the floor joist before the subfloor is installed. The bottom of the bridging is nailed in place after the subfloor is installed.
  - B. The bottom of the cross bridging is nailed to the floor joists. Next, the top of the bridging is nailed to the top of the floor joists, then the subfloor is installed.
  - C. The subfloor is installed. Next, the bridging is measured, marked, cut, and nailed in place from beneath the floor.
  - D. Before the subfloor is installed, the top and bottom of the bridging is installed.

10. When installing a plywood subfloor, what must you do to the floor end joints?
- A. Line them up
  - B. Center them
  - C. Sand them smooth
  - D. Stagger them

## LESSON 1

### PRACTICE EXERCISE

#### ANSWER KEY AND FEEDBACK

<u>Item</u>	<u>Correct Answer and Feedback</u>
1. A	Sills Sills are the horizontal . . . (page 1-1, para 1-1)
2. B	T, built-up, and box Box Sills. (page 1-1, para 1-1a); T-Sills. (page 1-2, para 1-1b); Built-Up Sills. (page 1-3, para 1-1c)
3. D	Girder Both the foundation walls and . . . (page 1-7, para 1-5)
4. C	3 x 12 Table 1-1 (page 1-6, para 1-4)
5. C	8 x 10 Table 1-1 (page 1-6, para 1-4)
6. A	Because heavily concentrated loads must be supported. In certain parts . . . (page 1-12, para 1-10a)
7. A	Joists resting upon sills and girders. A joist resting . . . (page 1-13, para 1-10b)
8. C	To stiffen the floor frame Floor frames are bridged . . . (page 1-15, para 1-11)
9. A	The top of the cross bridging is nailed to the top of the floor joist before the subfloor is installed. The bottom of the bridging is nailed in place after the subfloor is installed. Each piece is nailed . . . (page 1-15, para 1-11b)
10. D	Stagger them Arrange plywood . . . (page 1-16, para 1-12)



## **LESSON 2**

### **WALL-SYSTEM AND STAIRWAY CONSTRUCTION**

Critical Tasks: 051-236-1142  
051-236-1143  
051-236-2109

## **OVERVIEW**

### LESSON DESCRIPTION:

At the end of this lesson, you will be able to describe the construction of walls and stairs and the installation of doors and windows.

### TERMINAL LEARNING OBJECTIVE:

- ACTION:** You will describe how to construct a frame wall and how to install doors and windows.
- CONDITION:** You will be given the material contained in this lesson.
- STANDARD:** You will correctly answer the practice exercise questions at the end of this lesson.
- REFERENCES:** The material contained in this lesson was derived from FM 5-426.

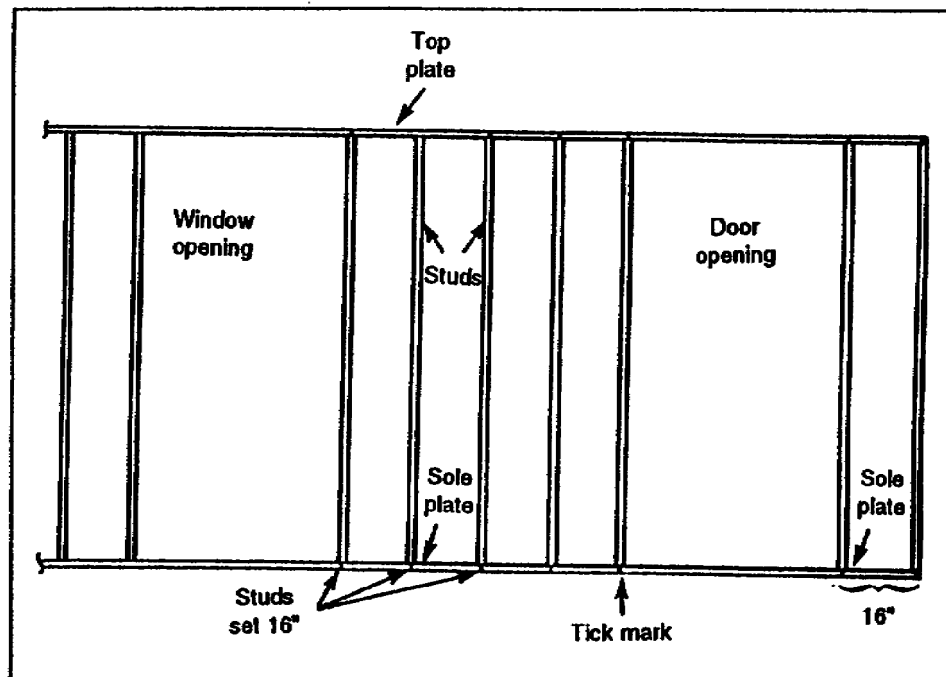
## **INTRODUCTION**

The primary objective of good construction is to erect a building that is structurally sound. The structure should withstand such forces as wind and vertical loads.

### **PART A - FRAMING MEMBERS**

Wall framing consists of studs, plates, braces, cripples, trimmers, headers, and fire blocks. It is supported by the floor system. Prefabricate the members of the frame wall on the floor of the building. Then raise the members into position and brace, nail, or bolt them in place.

**2-1. Studs.** Studs are closely spaced vertical members that support the weight of the upper floors. They provide a framework for exterior and interior finishes. Main studs can be spaced at 12, 16, or 24 inches on center. Lay out studs by measuring from one corner the distance the studs are to be spaced. Make a tick mark on the plate at the proper measurement (see Figure 2-1). After the window and door openings are determined, the studs are paced and nailed through the existing plates with 16d or 20d nails.



**Figure 2-1. Tick marks on the plate**

To gain the proper location and width of window and door openings you will need additional studs. Fasten the new studs to the plates in the same way as the previously installed studs. The new studs are not framed at 12, 16, or 24 inches on center (see Figure 2-2).

**2-2. Plates.** There are two types of plates—top and bottom (sole). The plates are laid out so the completed frame wall can be lifted easily and directly into place with the least amount of movement of the wall.

a. **Top Plates.** A horizontal member of a partition or frame wall is called a *top plate*. It serves as a cap for the studs and a support for the joist, rafters, and studs. Top plates tie the studs together at the top and ensure that the studs are aligned. They provide support for structural members above the plates and also provide a base for the roof rafters which tie the roof and walls together. To be effective, top plates should be doubled at the top of the walls and partitions and should have their joints staggered. (Double top plates are discussed in paragraph 2-9, page 2-12.)

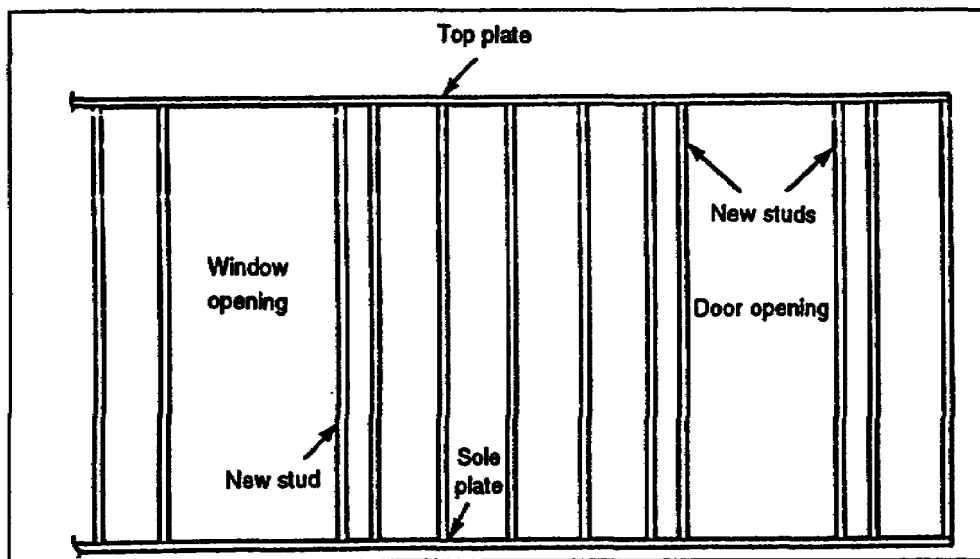


Figure 2-2. Placement of other studs

b. Sole Plates. Use a sole plate (with dimensions not less than the studs) where the walls do not rest on a sill, girder, or beam. Install the studs or corner posts at intervals that are evenly spaced except where partitions or walls are intersected.

**2-3. Door and Window Openings.** When framing door openings, it is desirable to double the studs. Cut short studs or trimmers the size of the opening and nail them to the inside face of the new studs (see Figure 2-3).

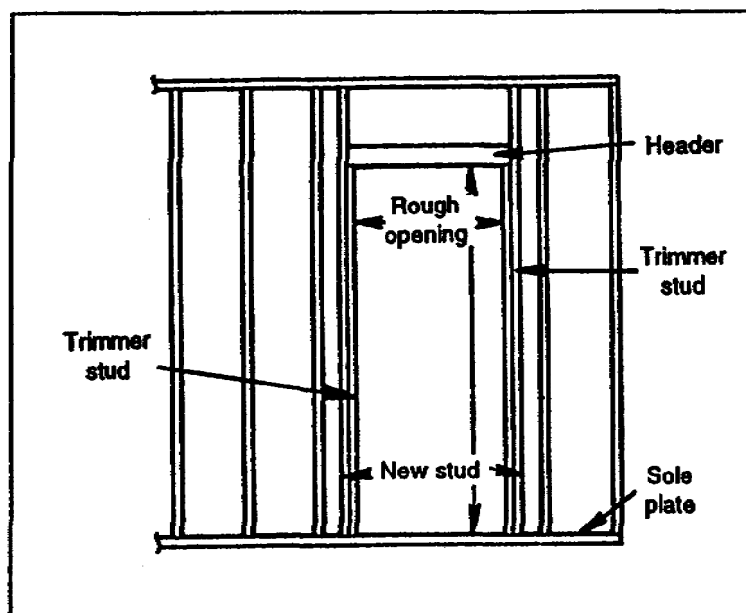
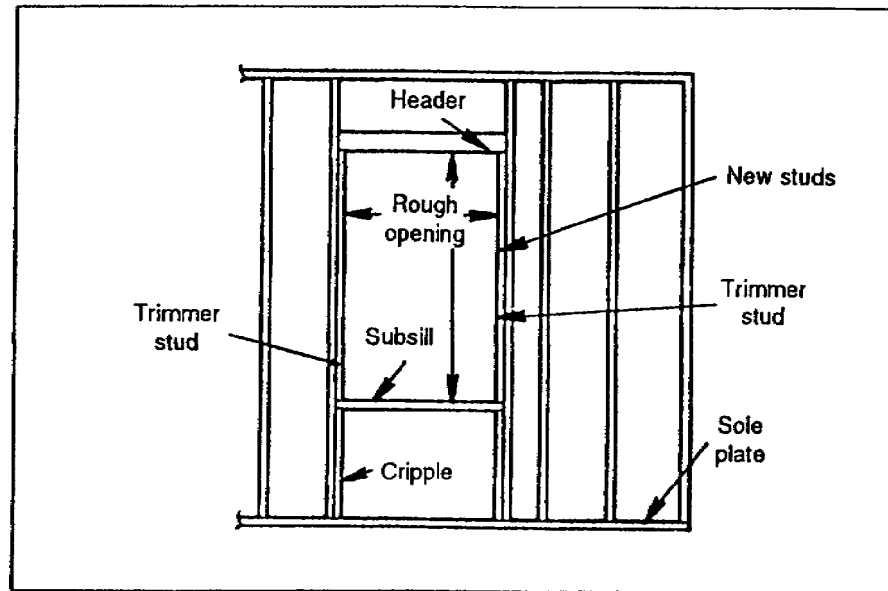


Figure 2-3. Frame for a door opening

a. Headers. Use 2 by 4 or 2 by 6 lumber to make a header. Double the header when this size of lumber is used. The size and the amount of lumber to be used in a header is determined by the width of the opening and the bearing load.

b. Subsill. When making a window opening, install a header over the window in the same way you would install a header over the door. A subsill must be framed between the trimmers and the cripples. The subsill can be either single or double. When doubled, nail the bottom piece to the outside studs at the proper height. Then nail the top piece of the sill to the bottom section (see Figure 2-4).



**Figure 2-4. Frame for window opening**

c. Cripples. Place the cripple or jack studs under and over the window and over door openings (see Figure 2-5). Cripples are placed at the same intervals as the ordinary studs and are installed after the openings are framed. These serve the same purpose as studs in the rest of the wall.

**2-4. Bracing.** Bracing is used to stiffen framed construction and make it rigid. Bracing is also used to resist winds, storms, twists, or strains. Good bracing keeps corners square and plumb. Bracing prevents warping, sagging, and shifting that could otherwise distort the frame and cause badly fitting doors and windows. The three methods commonly used to brace frame structures are let-in, cut-in, and diagonal-sheathing bracings. In some cases, temporary bracing may be used instead.

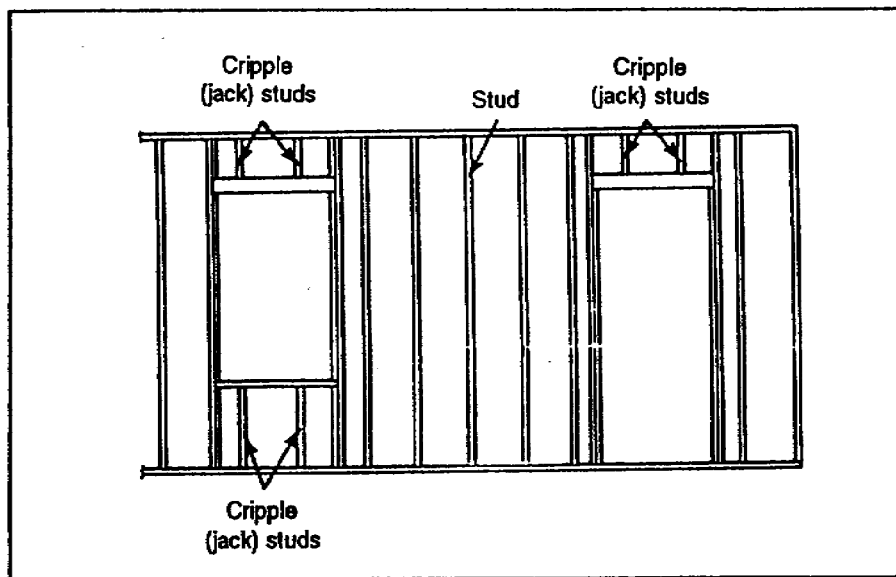


Figure 2-5. Cripples

a. Let-In Bracing. Let-in bracing is set into the edges of studs, flush with the surface. The studs are always cut to let in the braces; the braces are never cut (see Figure 2-6).

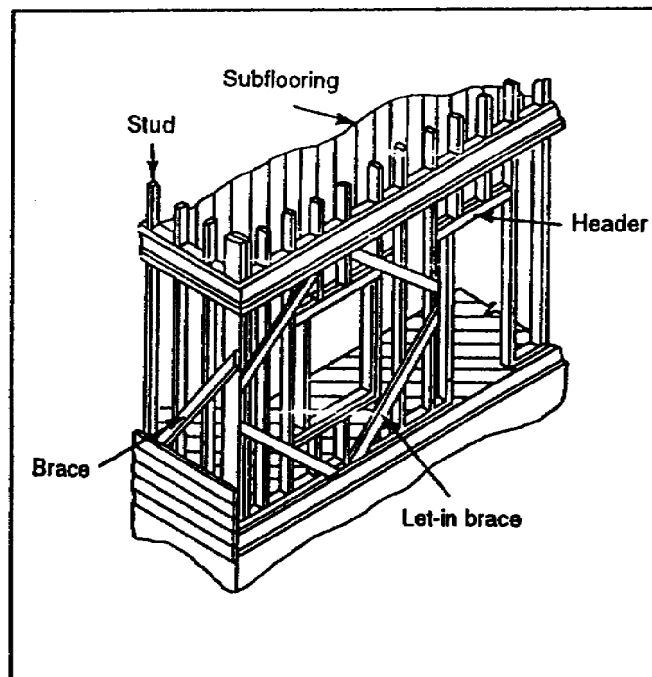
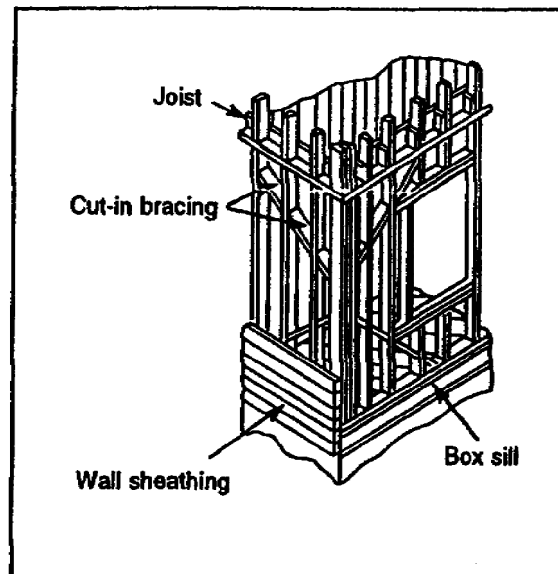


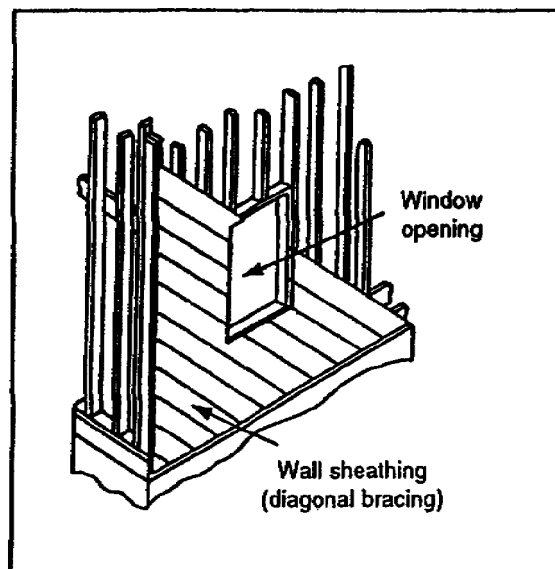
Figure 2-6. Let-in bracing

b. Cut-In Bracing. Cut-in bracing is toenailed between studs. They are inserted in diagonal progression between studs running up and down from corner posts to the sole plate, top plate, or sills (see Figure 2-7).



**Figure 2-7. Cut-in bracing**

c. Diagonal-Sheathing Bracing. The strongest type of bracing is diagonal sheathing (see Figure 2-8). Each board braces the wall. If plywood sheathing 5/8 inch thick or more is used, other methods of bracing may be omitted.



**Figure 2-8. Sheathing used as diagonal bracing**

d. Temporary Bracing. Temporary bracing is placed at intervals small enough to hold the wall straight (see Figure 2-9). Bracing placed diagonally on the studs running from the sole plate to the top plate will increase the strength of the wall against horizontal stress (see Figure 2-10).

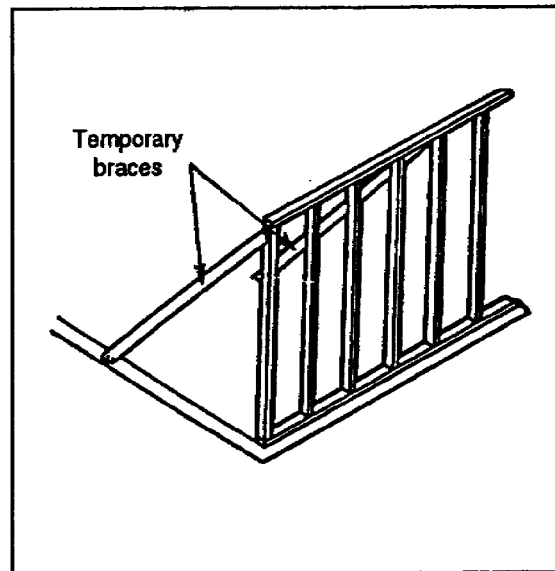


Figure 2-9. Temporary bracing

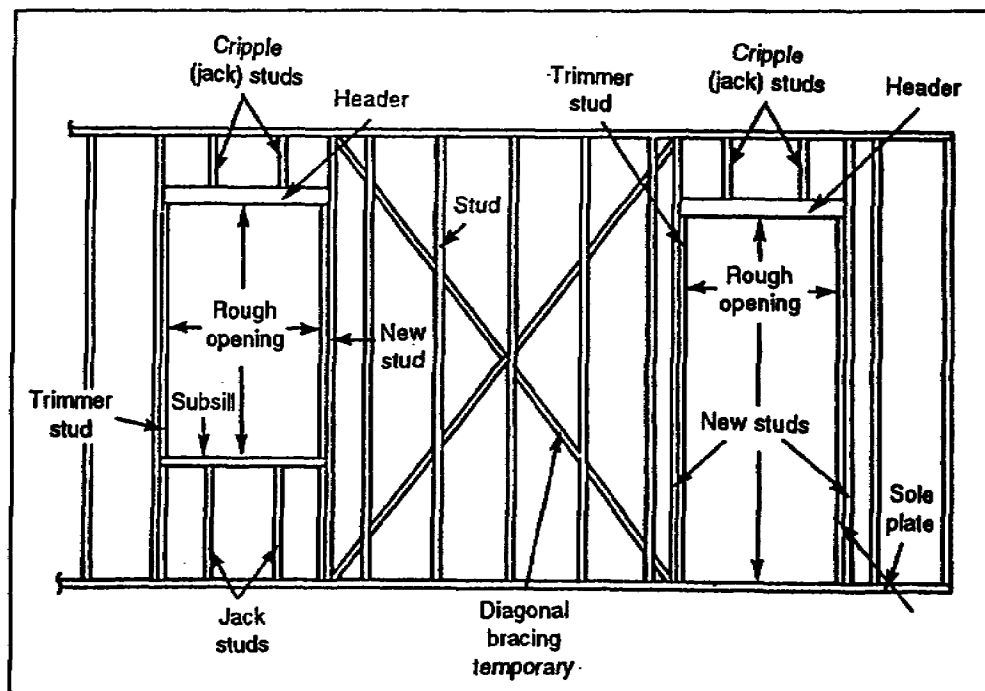


Figure 2-10. Temporary diagonal bracing

**2-5. Fire Blocks.** Fire blocks are short pieces of 2 by 4s cut to fit snugly between the studs. They are placed midway up the wall, between the studs to prevent the spread of fire inside the wall. The use of fire blocks will differ according to local building codes. Figure 2-11 shows the proper placement of fire blocks.

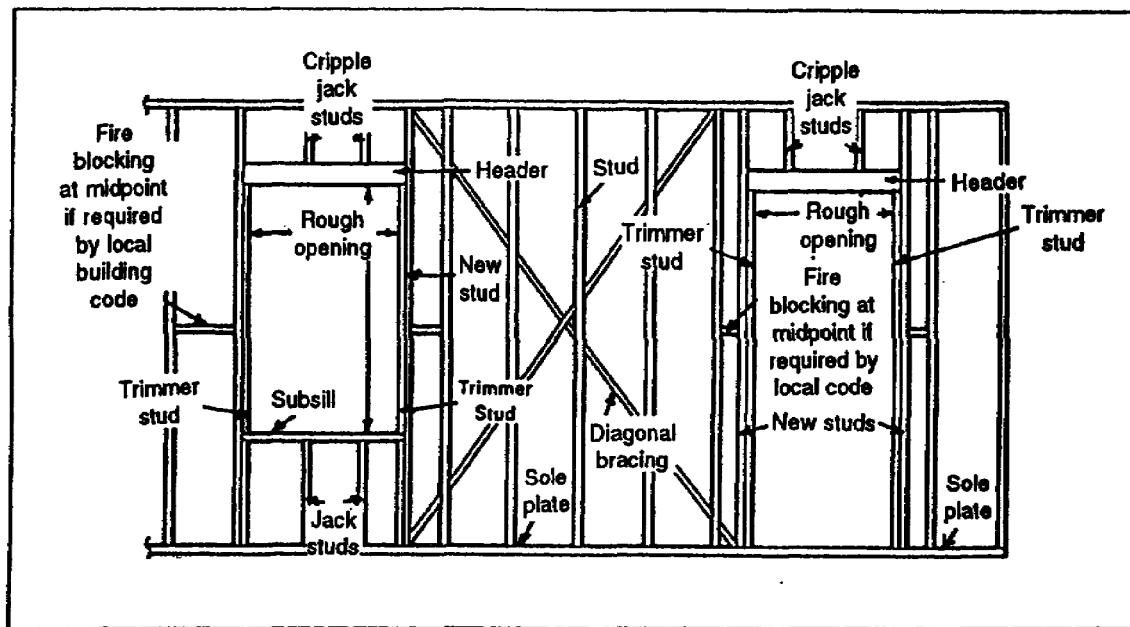


Figure 2-11. Fire block placement

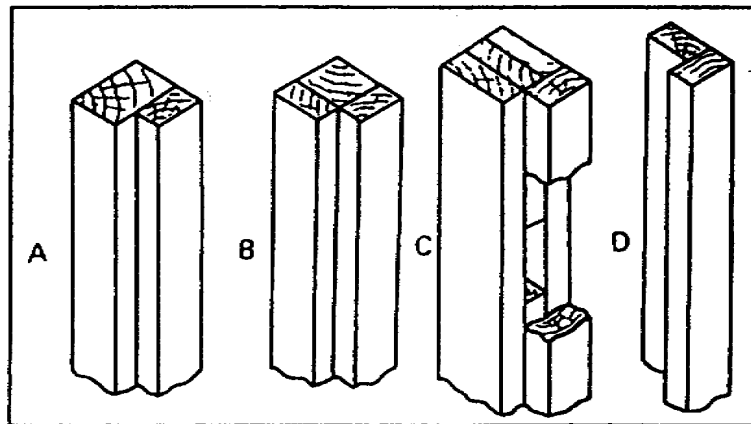
**2-6. Post Construction.** Where partitions meet other walls and at the corners, the studs are built-up using three or more regular 2 by 4s to provide greater strength. Corner posts and T-posts are the most frequently used.

a. **Corner Post.** A corner post forms an inside corner and an outside corner, which provides a good nailing base for inside wall coverings. The studs used at the corners of frame construction are usually built up from three or more ordinary studs to provide greater strength. These built-up assemblies are called *corner posts*. They are set up, plumbed, and temporarily braced. Corner post may also be made in any of the following ways (see Figure 2-12).

- A 4 by 6 with a 2 by 4 nailed on the board side flush with one edge (see Figure 2-12, A). This type of corner is for a 4-inch wall. Where walls are thicker, heavier timber is used.
- A 4 by 4 with a 2 by 4 nailed to each of two adjoining sides (see Figure 2-12, B).
- Two 2 by 4s nailed together with blocks between them and a 2 by 4 flush with one edge (see Figure 2-12, C). This is the most common method.



- A 2 by 4 nailed to the edge of another 2 by 4, the edge of one flush with the side of the other (see Figure 2-12, D). This type is used extensively in the theater of operations, where no inside finish is needed.



**Figure 2-12. Corner-post construction using both 2-inch and 4-inch lumber**

b. T-Posts. Whenever a partition meets another wall, a stud wide enough to extend beyond the partition on both sides is used. This provides a solid nailing base for the inside wall finish. This type of stud is called a *T-post* and is made in any of the following ways (see Figure 2-13, page 2-10):

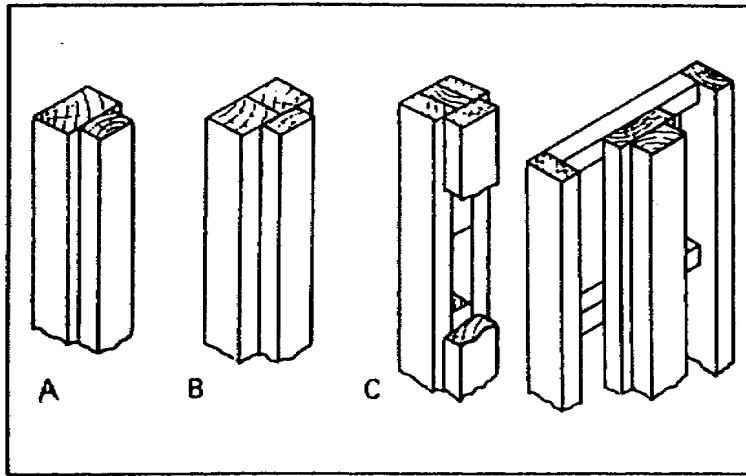
- A 2 by 4 may be nailed and centered on the face side of a 4 by 6 (see Figure 2-13, A).
- A 2 by 4 may be nailed and centered on two 4 by 4s nailed together (see Figure 2-13, B).
- Two 2 by 4s may be nailed together with a block between them and a 2 by 4 centered on the wide side (see Figure 2-13, C).
- A 2 by 4 may be nailed and centered on the face side of a 2 by 6, with a horizontal bridging nailed behind them to give support and stiffness (see Figure 2-13, D).

## **2-7. Plumbing Posts.** There are two methods for plumbing posts.

a. Method 1. To plumb a corner with a plumb bob--

(1) Attach a string to the bob. The string should be long enough to extend to or below the bottom of the post.

(2) Lay a rule on top of the post so that 2 inches of the rule extend over the post on the side to be plumbed.



**Figure 2-13. T-post construction**

(3) Hang the bob line over the rule so that the line is 2 inches from the post and extends to the bottom of it. Refer to Figure 2-14.

(4) With another rule, measure the distance from the post to the center of the line at the bottom of the post. If it does not measure 2 inches, the post is not plumb.

(5) Move the post inward or outward until the distance from the post to the center of the line is exactly 2 inches, then nail the temporary brace in place.

(6) Repeat this procedure from the other outside face of the post. The post is then plumb.

**NOTE: Follow this process for each corner post of the building. If a plumb bob or level is not available, use a rock, half-brick, or small piece of metal.**

b. Method 2. An alternate method of plumbing a post is shown in the inset in Figure 2-14. To use this method--

(1) Attach the plumb-bob string securely to the top of the post to be plumbed. Be sure that the string is long enough to allow the plumb bob to hang near the bottom of the post.

(2) Use two blocks of wood, identical in thickness, as gauge blocks.

(3) Tack one block near the top of the post between the plumb-bob string and the post (guard block 1).

- (4) Insert the second block between the plumb-bob string and the bottom of the post (gauge block 2).
- (5) If the entire face of the second block makes contact with the string, the post is plumb.

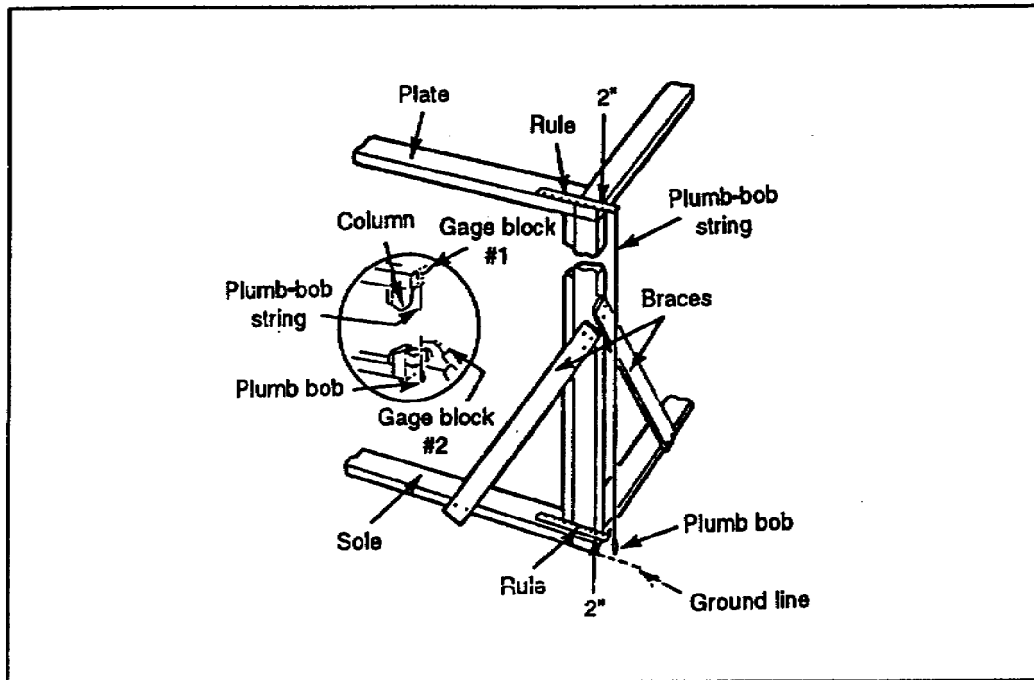


Figure 2-14. Plumbing a post

**2-8. Bridging** The term *bridging* is used to refer to a system for bracing joists and studs. Frame walls are bridged in most cases, to make them more sturdy. Two types of bridging are diagonal and horizontal.

a. **Diagonal Bridging.** Diagonal bridging is nailed at an angle between the studs (see Figure 2-15, page 2-12). It is more effective than the horizontal type because it forms a continuous truss and keeps the wall from sagging. Whenever possible, both interior partitions and exterior walls should be bridged alike.

b. **Horizontal Bridging.** Horizontal bridging is nailed between the studs horizontally and halfway between the sole and top plates. This type of bridging is cut to fit between the studs. The measurements should be taken at the sole plate in case the studs are warped. Such bridging not only stiffens the wall but also helps to straighten the studs. Notice that the bridging is staggered in Figure 2-16, page 2-12.

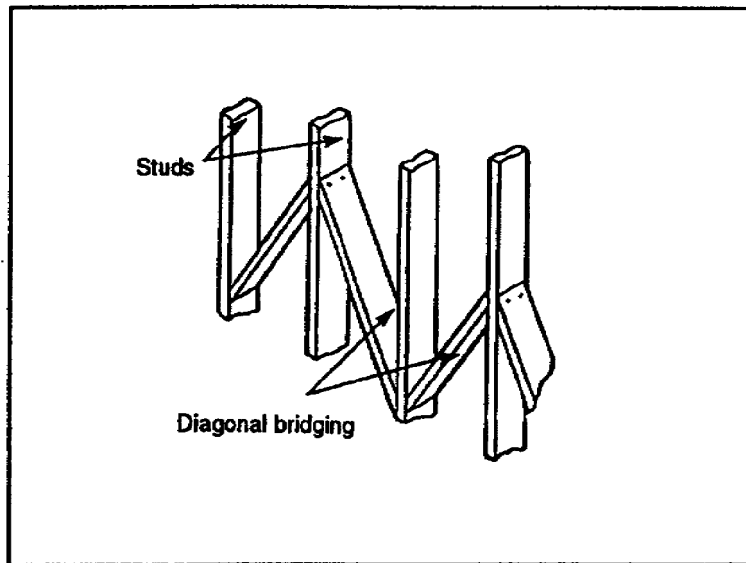


Figure 2-15. Diagonal bridging

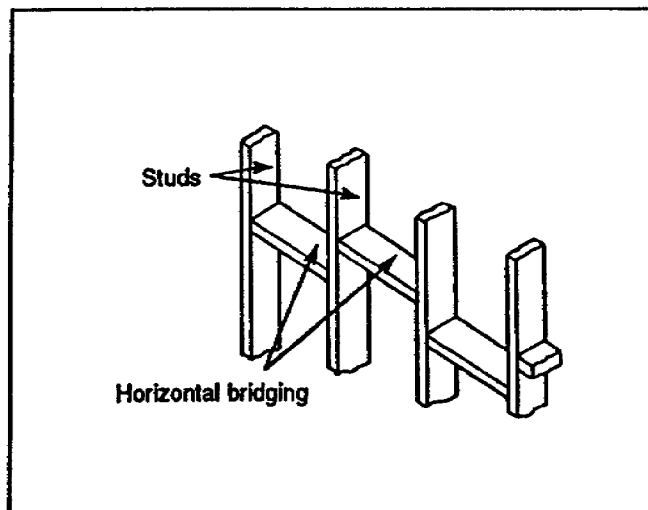
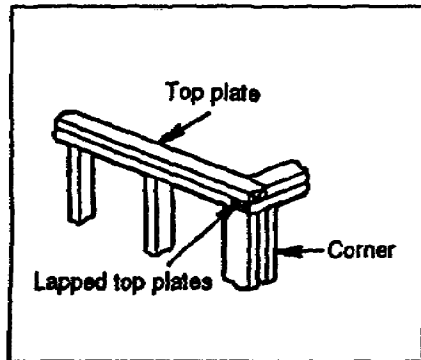


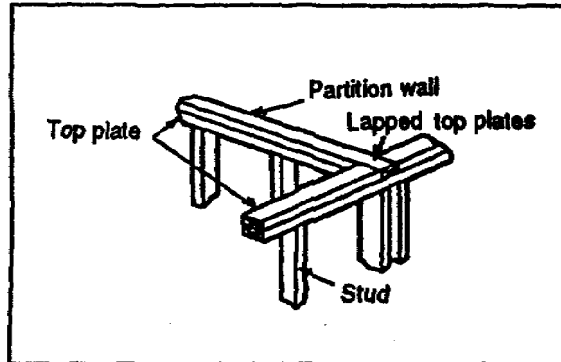
Figure 2-16. Horizontal bridging

**2-9. Double Top Plates.** After the frame walls are assembled and set in place, they must be tied together. Use a double top plate to interlock exterior walls at the corner and load-bearing partition walls. Overlap the double top plates at the corners (see Figure 2-17). Tie load-bearing partition walls into the exterior walls

by leaving an opening in the top plate of the outside wall. This allows the double top plate to fit into place. Or cut out a piece of the double top plate to allow the overlap to fit (see Figure 2-18).



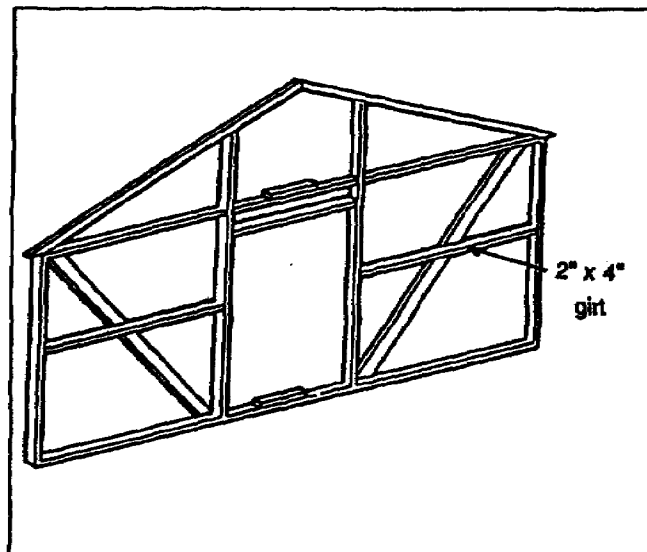
**Figure 2-17. Lapped at the corner**



**Figure 2-18. Lapped at the partition wall**

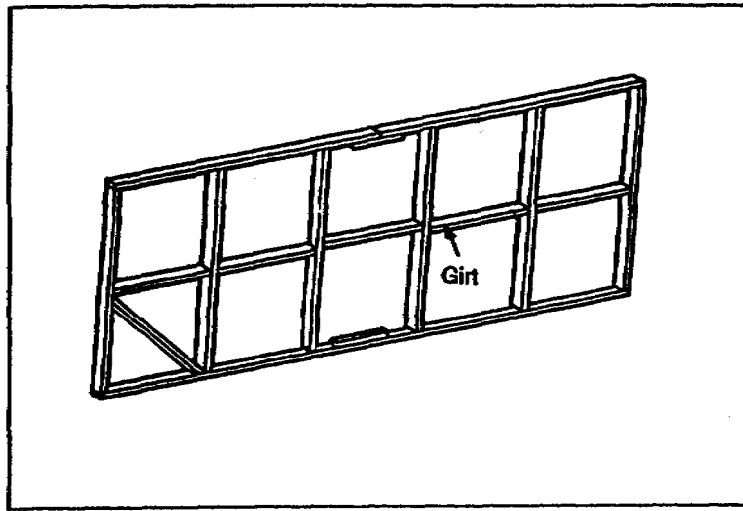
**2-10 Hasty Wall Construction.** Hasty wall construction is used frequently in the theater of operations. This type of construction uses less material and requires less time. The panels used most are end wall and sidewall.

a. End-Wall Panels. The walls at the end of the building have studs that extend to the rafters and do not require a top plate (see Figure 2-19).



**Figure 2-19. End-wall panels**

b. Sidewall Panels. Place studs from 2 to 10 feet apart, with girts placed horizontally between the studs to construct sidewalls (see Figure 2-20). Vertical siding is normally used in this type of construction.



**Figure 2-20. Sidewall panels**

## **PART B - WALL SHEATHING**

After completing the framework of a building, fasten a covering, known as *sheathing*, to it. Sheathing includes exterior wall sheathing, finish siding, and interior wall sheathing.

**2-11. Exterior Wall Sheathing.** Sheathing is nailed directly onto the framework of the building. It is used to strengthen the building; provide a base wall to which finish siding can be nailed; act as insulation; and, in some cases, be a base for further insulation. Some common types of sheathing include wood, gypsum board, and plywood.

a. Wood Sheathing. Wood sheathing may be nailed on horizontally or diagonally (see Figure 2-21) however, diagonal application adds much greater strength to the structure. If the sheathing is to be put on horizontally, start at the foundation and work toward the top. If it is to be put on diagonally, start at the corner of the building and work toward the opposite wall.

b. Gypsum Board. The long edges of the 4 by 8 boards are tongue-and-grooved. Gypsum board can be nailed (together with the wood siding) directly to the studs. Gypsum sheathing is fireproof, water resistant, and windproof. It does not warp or absorb water and does not require the use of building paper (see Figure 2-22).

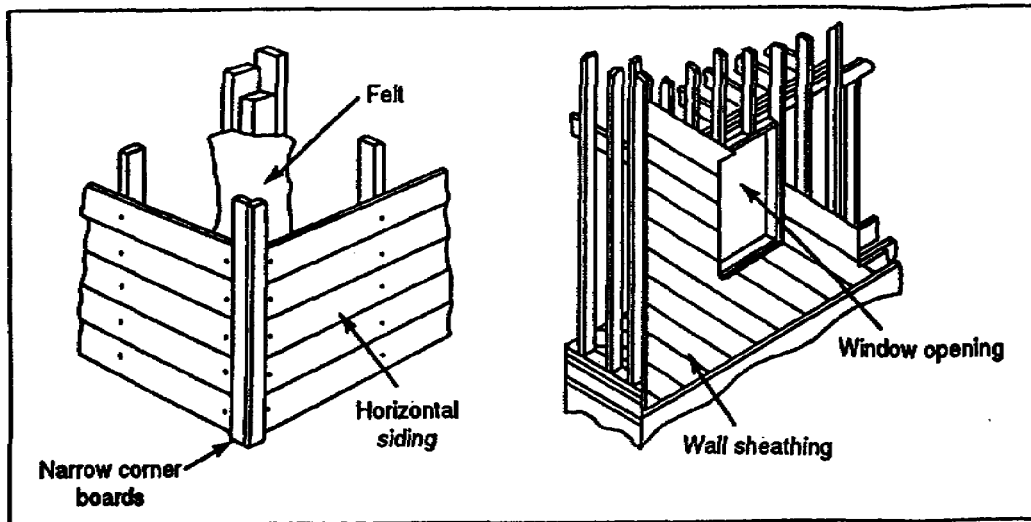


Figure 2-21. Wood sheathing

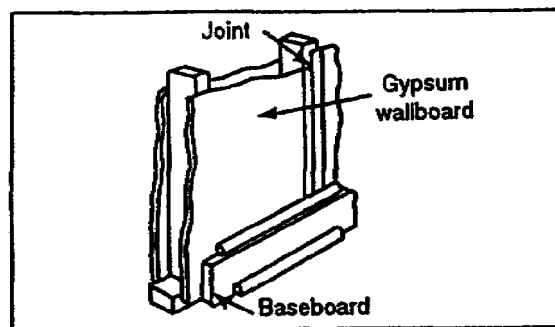


Figure 2-22. Gypsum board sheathing

c. Plywood. Plywood is highly recommended for wall sheathing because of its weight, strength, and structural properties. Plywood is most commonly used because it adds a lot more strength to the frame than using diagonally applied wood boards. It comes in 4-foot-wide and 5- to 8-foot-long sheets, 1/4 to 3/4-inch thick. Install the sheets with the face grain parallel to the studs (see Figure 2-23, page 2-16). It is usually applied vertically from the floor to the ceiling. When plywood is correctly applied (with flush joints), the joints do not need to be concealed. However, to improve wall appearance, joints may be covered with moldings. These may be battens fastened over the joints or applied as *splines* between the panels. Less-expensive plywood can be covered with paint or covered in the same way as plastered surfaces. Figure 2-24, page 2-16, shows how to fit plywood on rough or uneven walls.

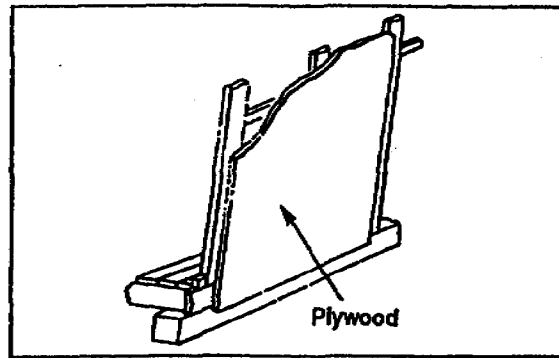


Figure 2-23. Plywood sheathing

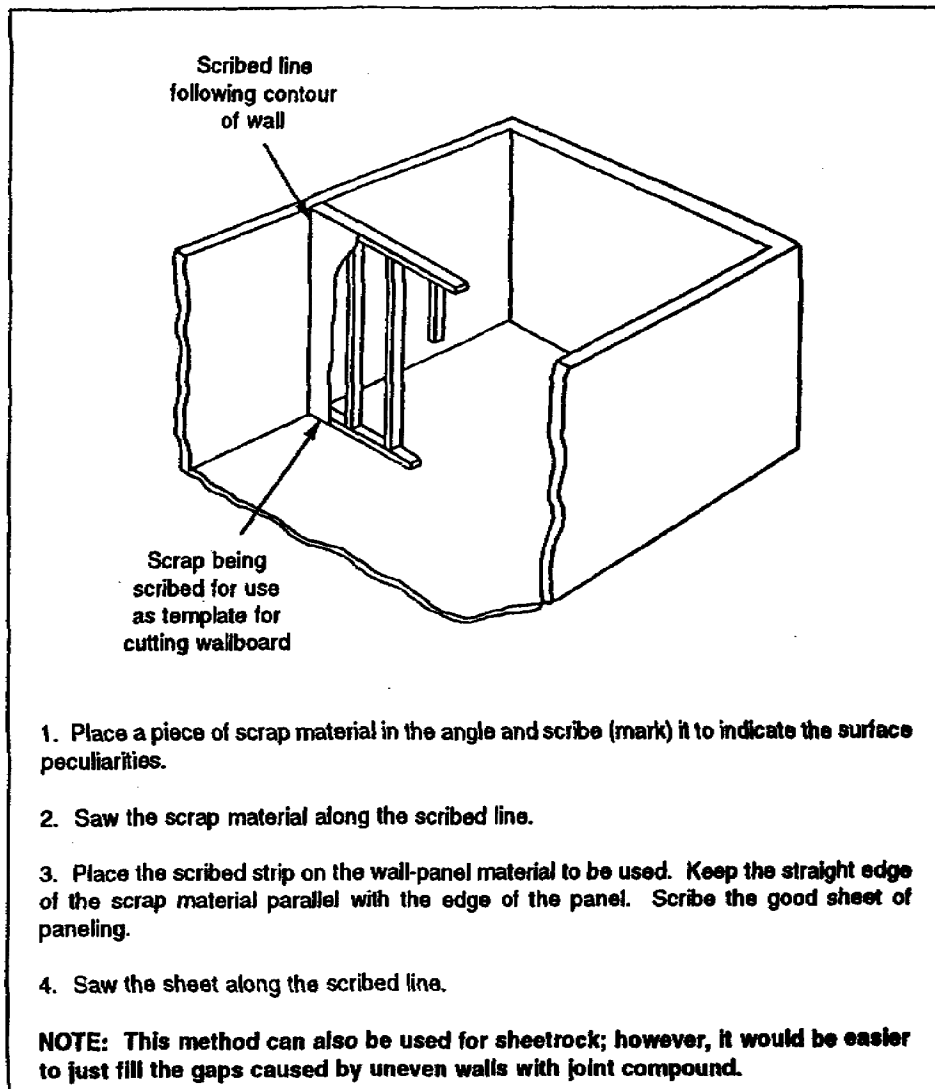
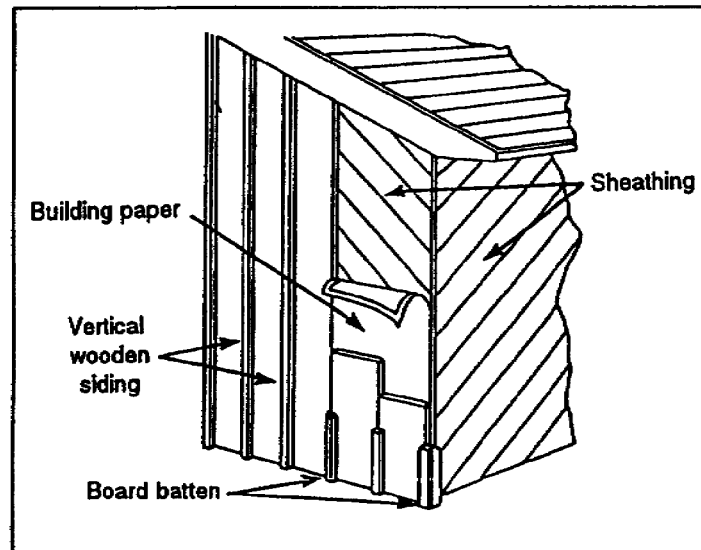


Figure 2-24. Fitting wall panels to uneven walls



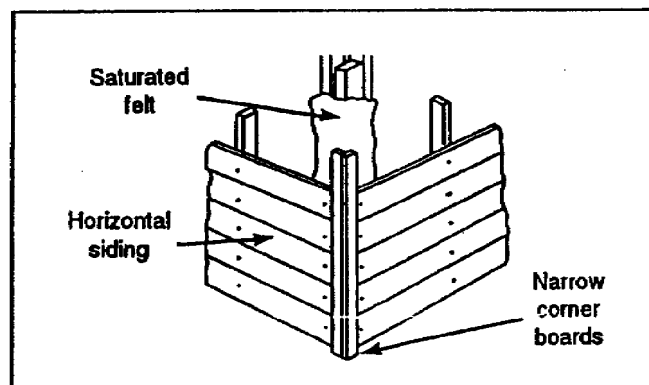
**2-12. Finish Siding.** Finish siding is the outside wood finish of the wall. Only board siding made of long, narrow boards will be covered in this section.

a. **Vertical Wood Siding.** Vertical wood siding is nailed securely to girts with 8d or 10d nails. The cracks are covered with wood strips called *battens*. To make this type of wall more weatherproof some type of tar paper or light-roll roofing may be applied between the siding and the sheathing. (See Figure 2-25.)



**Figure 2-25. Vertical wood siding**

b. **Horizontal Wood Siding.** Horizontal wood siding is cut to various patterns and sizes to be used as the finished outside surface of a structure (see Figure 2-26). It should be well-seasoned lumber. Siding is made in sizes ranging from 1/2 inch to 1 inch by 12 inches. Two types of siding are beveled and drop.



**Figure 2-26. Horizontal wood siding**

(1) Beveled Siding. Beveled siding is made with beveled boards, thin at the top edge and thick at the butt (see Figure 2-27). It is the most common form of wood siding. It comes in 1 inch for narrow widths and 2 inches and over for wide types. It is nailed to solid sheathing, over which building paper has been attached.

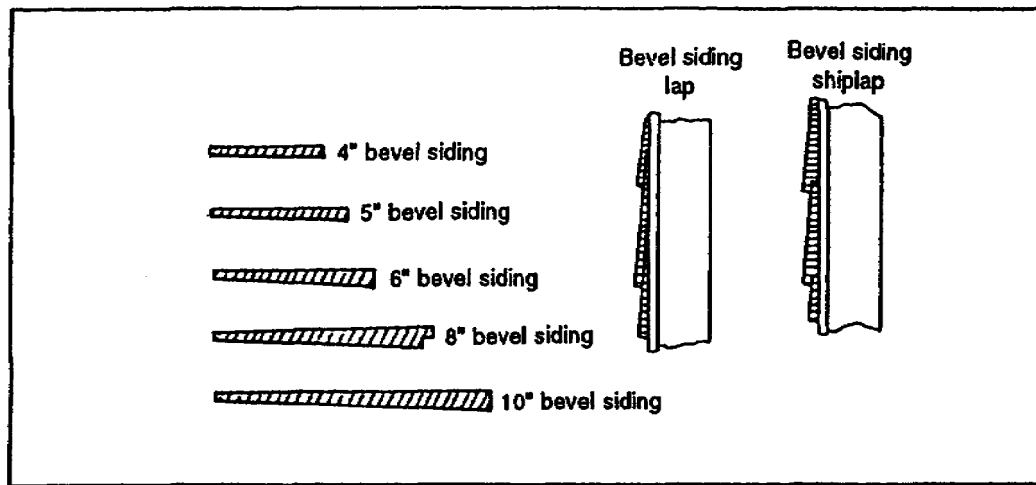


Figure 2-27. Beveled siding

(2) Drop Siding. Drop siding is used as a combination of sheathing and siding or with separate sheathing. It comes in a wide variety of face finishes and is either shiplapped or tongue-and-grooved (see Figure 2-28). When sheathing is not used, the door and window casings are set after the siding is up. If sheathing is used and then building paper is added, drop siding is applied with beveled siding, after the window and door casings are in place.

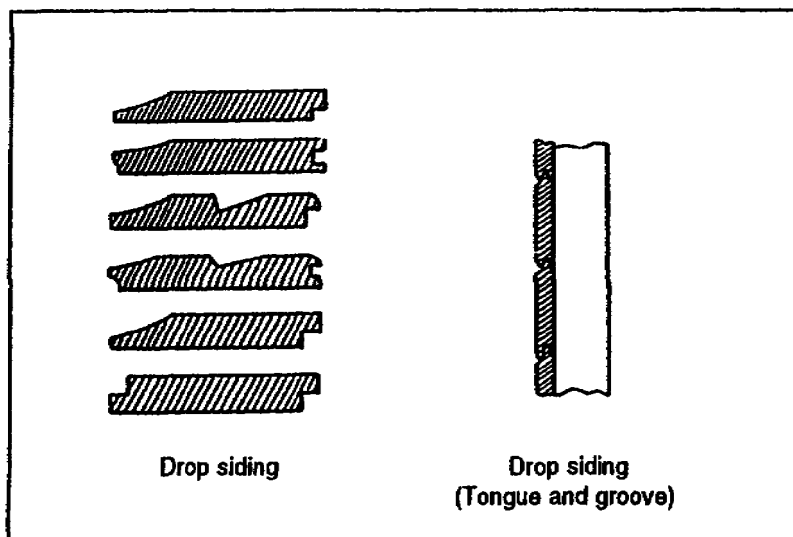
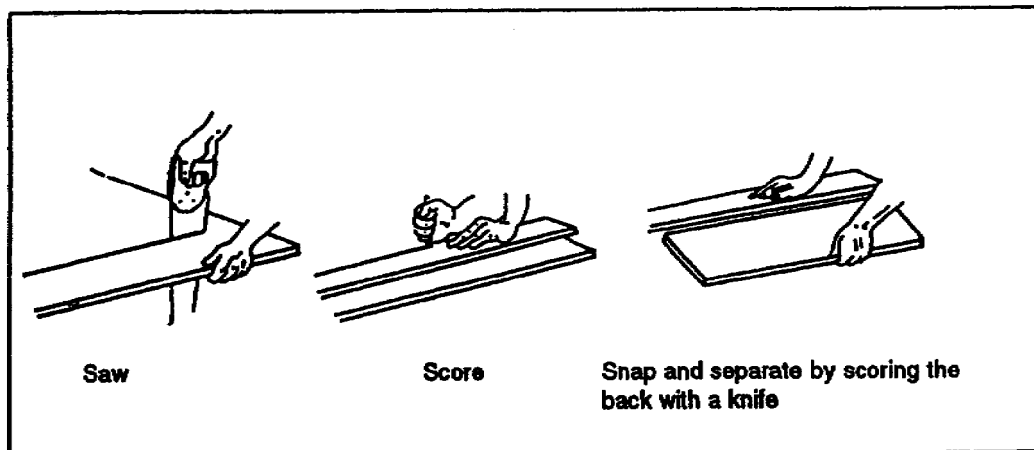


Figure 2-28. Drop siding

**2-13. Sheetrock Tools.** The following are tools used in the application of sheetrock:

- a. The sheetrock hammer is used for hammering nails.
- b. The sheetrock carrier (lifter) is used for carrying and lifting sheetrock.
- c. Sheetrock knives are used to apply and finish joint compound. The 4-inch knife is used to bed the tape in the first layer of joint compound and for filling the dimples, the 6-inch knife is used for feathering out the second coat, and the 12-inch knife is used for the third/finish coat.
- d. The corner trowel flexes from 90° to 103°. It is used to apply joint compound in interior corners.
- e. The mud pan is used to hold and carry joint compound.
- f. The corner-bead crimper is used to fasten the corner bead by crimping.
- g. The T-square is used to lay out and guide a 90° cut on sheetrock.
- h. The utility knife is used to score or cut the sheetrock (see Figure 2-29).



**Figure 2-29. Cutting sheetrock**

- i. The keyhole saw is used for cutting irregular shapes and openings (such as outlet-box openings).
- j. Surform is used to smooth sheetrock edges after cutting.
- k. The tape banjo is used to apply tape (dry) or joint compound and tape (wet).
- l. Sandpaper and sponges are used for feathering or smoothing dried joint compound.

- m. A chalk line is used to facilitate layout.
- n. A 16-foot measuring tape is used for measuring the sheetrock.
- o. A 4-foot hand level is used to plumb.
- p. Sawhorses are used for placing sheetrock on to make cut.

**2-14. Interior Wall Coverings.** Interior wall coverings are divided into two general types: wet wall material (such as plaster) and drywall material (including wood, sheetrock, plywood, and fiberboard). Only drywall will be covered in this subcourse.

a. Drywall. Sheetrock, fiberboard, and plywood usually comes in 4-foot-wide and 5- to 8-foot-long sheets, 1/4 to 3/4 inch thick. Drywall is applied in either single or double thicknesses with panels placed as shown in Figure 2-30. When covering both walls and ceilings, always start with the ceilings. Use annular ringed nails when applying finished-joint drywall to reduce nail pops.

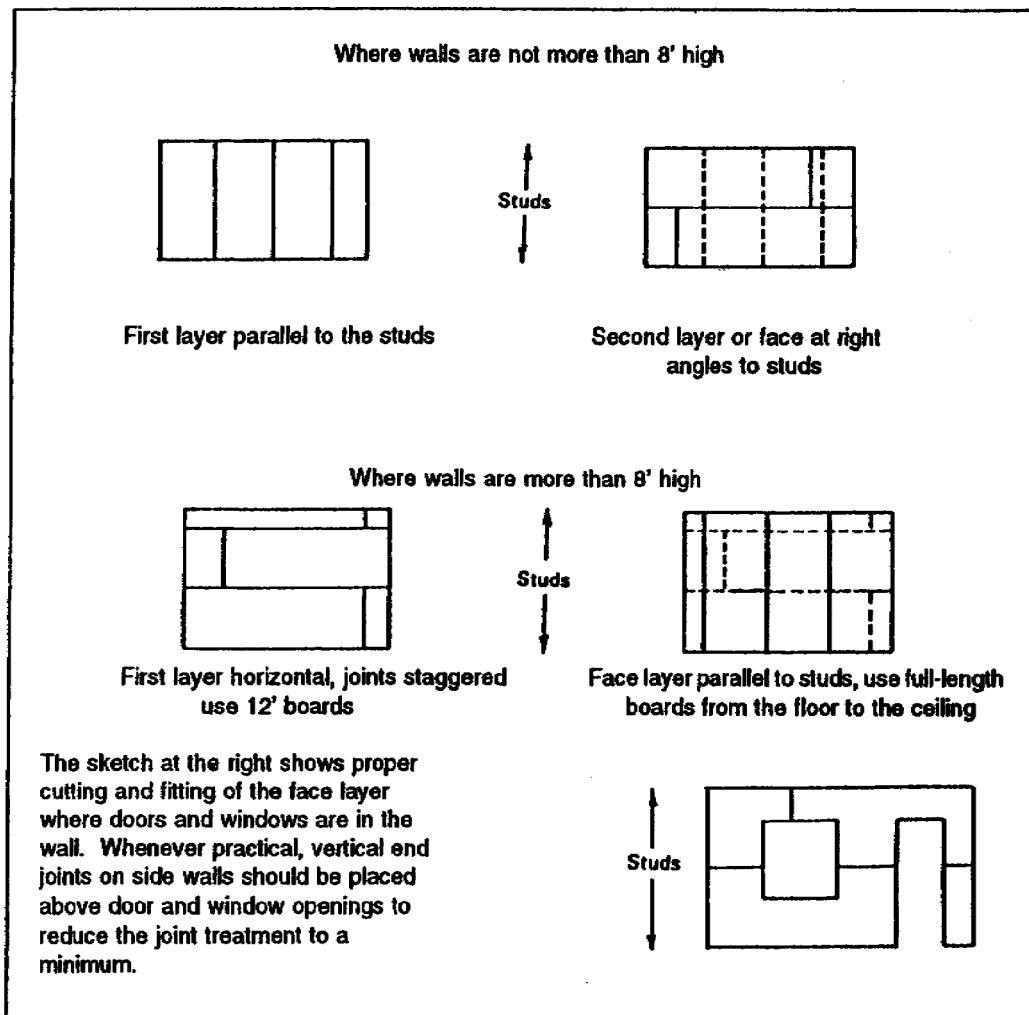


Figure 2-30. Drywall placement

b. Drywall (Sheetrock) Installation. The three steps to installing sheetrock are hanging, finishing, and patching.

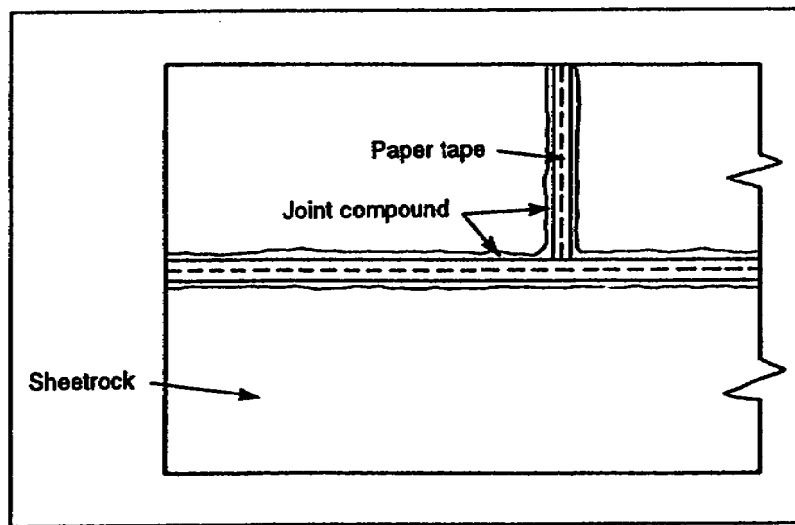
(1) Hanging Sheetrock. Apply sheetrock as follows:

- Install sheetrock on the ceiling first. Measure the distance from the inside edge of the top plate to the outside edge of the second ceiling joist. Measure and cut a piece 48 inches long to the width measured above. Install and secure the sheet to the ceiling with sheetrock nails. Nail spacing on ceilings is 5 to 7 inches on center.
- Determine the starting point of the wall. Using a measuring tape, locate a section where the studs are 8 foot on center and where a full sheet could be laid horizontally. Check the layout to ensure that there will be no joints above or below the door or window openings. Sheets will be installed from the ceiling down to the floor, starting at the ceiling.
- Install the first sheet. With the help of another person, place a sheet of sheetrock in position so that the edges fall on the center of the studs. Place the sheet snug against the ceiling, using a hand level to ensure that it is level. Secure the sheet with sheetrock nails 6 to 8 inches on center, 3/8 inch from the edge. Install succeeding sheets on the top half of the wall against installed sheets, ensuring that joints fall on the center of the studs and that proper nail spacing is maintained. Using a utility knife or sheetrock saw, cut out openings for doors and windows.
- Lay out the receptacles. Measure the distances from an inside corner to both sides of the receptacle box and record them. Measure the distance from the installed sheetrock to the top and bottom of the receptacle box, and record it. Measure and mark these dimensions for the receptacle cutout, allowing 1/16-inch clearance all around.
- Cut out the opening for the receptacle. With a utility knife, drive a hole within the opening. Using a keyhole saw, cut out the opening. Use a slight undercut bevel so that the back opening is larger than the front opening.
- Install the prepared sheet. Place the prepared sheet in position, ensuring that the receptacle fits in the opening without breaking the paper. Make adjustments to the opening if necessary. Secure the sheet to the studs with sheetrock nails. Using a Surform, smooth the rough edges of the openings as necessary.
- Lay out and cut sheets for corner posts. Measure and cut the required number and sizes of sheets to cover corner posts. Use scrap pieces of material if needed.

- Install the corner bead. Using a corner-bead crimper, install the corner bead on the exterior corners of corner posts. Use nails if necessary.

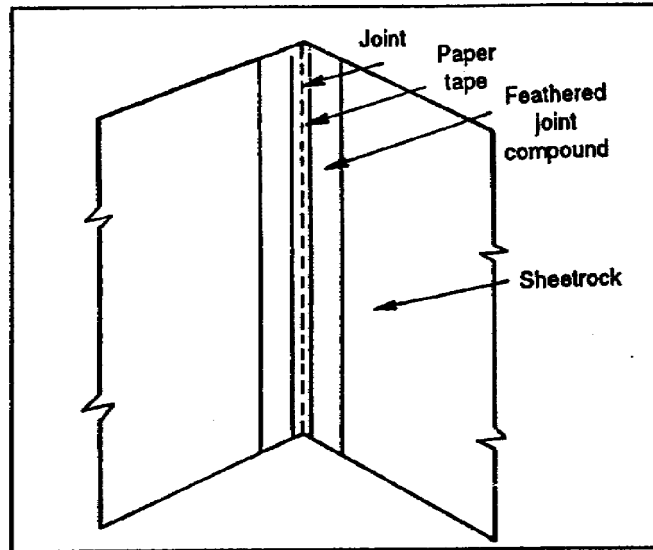
(2) **Finishing Sheetrock** The finishing process consists of covering nailheads and covering seams (covering seams is also referred to as *finishing joints*). Finish sheetrock as follows:

- Check for improperly recessed nails by running the edge of a sheetrock knife over the nailheads. A clicking sound indicates a nail needing to be recessed.
- Use a 4-inch knife and mud pan with joint compound to apply a smooth coat of joint compound over the nails. Remove any excess compound.
- Use the knife and mud pan to apply a heavy coat of joint compound over a sheetrock joint, horizontal or vertical. A heavy coat is enough to ensure a good bond between the tape and sheetrock and to fill in tapered edges. Measure and cut the tape to the length required for a joint (see Figure 2-31). Keeping the tape centered over the joint, start at one end of the joint and work toward the opposite end. Using the knife, press the tape into the compound, removing all excess compound. Work off all excess joint compound, being careful not to wrinkle the tape or leave air bubbles. Continue to tape all the joints in the same manner.



**Figure 2-31. Covering joints**

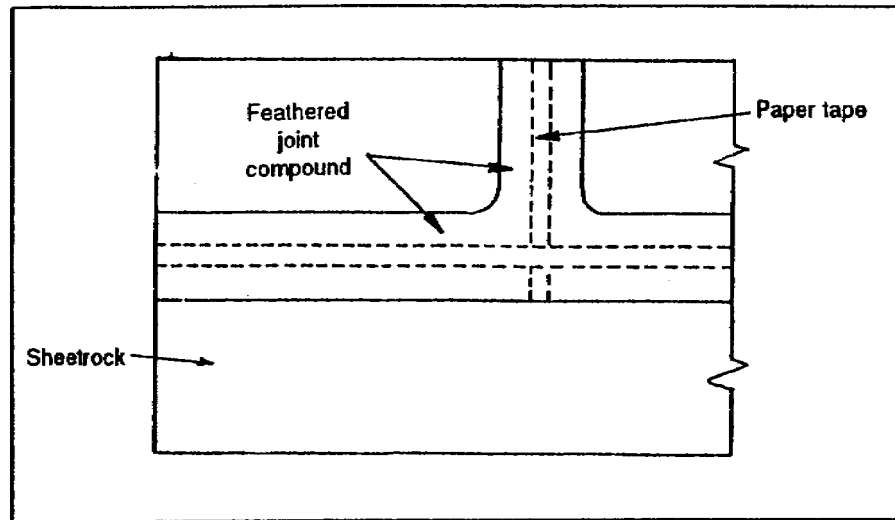
- Use a 4-inch knife to apply a heavy coat of joint compound over the sheetrock at the inside corner (see Figure 2-32). Measure and cut the tape to the length required for the joint. Fold the tape in half lengthwise, keeping both edges even. Use a corner tape creaser if necessary. Apply the tape at the top and work downward, running the edge of your hand at the center of the tape to ensure that it is in the corner. Using the inside corner tool, press the tape into the compound, working off all excess compound and being careful not to wrinkle the tape or leave air bubbles.



**Figure 2-32. Applying tape at corners**

- Apply the first coat of joint compound over the tape then apply a medium coat of joint compound. Feather the compound with the 6-inch knife to about 2 to 3 inches on each side of the joint. A good job of feathering and smoothing will minimize sanding later.
- Apply the second coat of joint compound over the tape and nail coverings. The joint compound previously applied must be completely dry. Use the 4-inch knife to apply a thin coat of compound over the nails, removing any excess compound. Using the steps above, apply the second coating to the joints using the 6-inch knife and feathering out 6 to 8 inches on each side of the joint.
- Apply the third coat of joint compound (see Figure 2-33, page 2-24). The joint compound previously applied must be completely dry. Using the step above, apply the third coat using the 10-inch knife and feathering out 10 to 12 inches on each side of the joint. Nails should not require a third coat, but it may be applied if necessary.

- Using a damp sponge or fine sandpaper, sand the surface to a smooth finish, ensuring that there are no voids and that the surface is ready to receive paint.



**Figure 2-33. Finishing the joints**

(3) Patching Sheetrock. There are several different methods of patching sheetrock, depending on the size of the hole.

- For small holes, apply fiber-mesh tape directly over the hole. Cut the tape with joint compound and feather the edges. Sand or sponge the area smooth after it has dried.
- For fist-size holes, cut out a rectangle around the hole with a keyhole saw. Cut a piece of backing (1 by 2 or 1 by 3) slightly larger than the opening itself. Glue or screw the backing into place. Cut a patch and glue it to the backing using either wallboard adhesive or mastic. Apply tape and coat it with compound. Feather the edges. Sand or sponge the area smooth after it has dried.
- For large holes, mark and cut a rectangular section around the damaged area, reaching from the centers of the nearest studs. Cut a patch and screw or nail it to the studs. Apply tape and coat it with compound. Feather the edges. Sand or sponge the area smooth after it has dried.

## **PART C - MOLDINGS**

The different trims of a building, which have a definite architectural relationship to the design of the building, are called *moldings*.



**2-15. Base Moldings.** The interior trim of a building should match or complement the design of the doors, the windows, and the building. Base molding is the trim between the finished wall and the floor. It is available in several widths and forms. Two-piece base consists of a baseboard topped with a small base cap (see Figure 2-34). The common size for this type baseboard is 1 by 4 inches or wider. One-piece baseboard varies in size from 1/2 by 3 inches to 1 by 4 inches and wider (see Figure 2-35). Although a wood member is desirable at the junction of the wall and carpeting to serve as a protective bumper, wood trim is sometimes eliminated entirely.

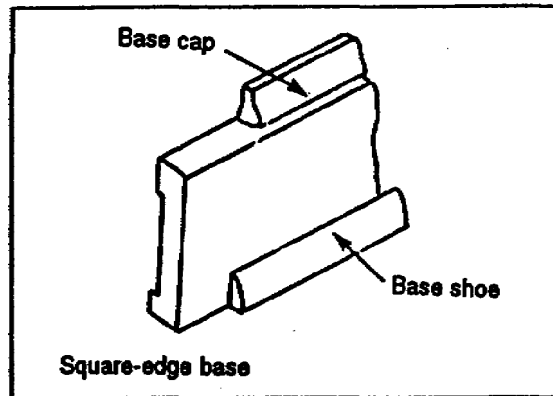


Figure 2-34. Two-piece baseboard

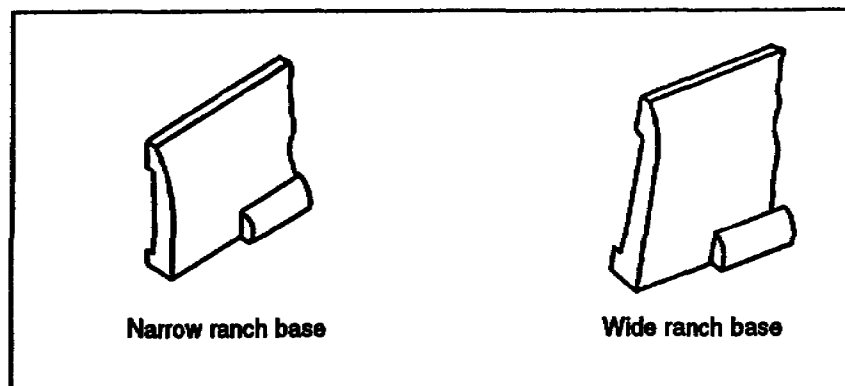
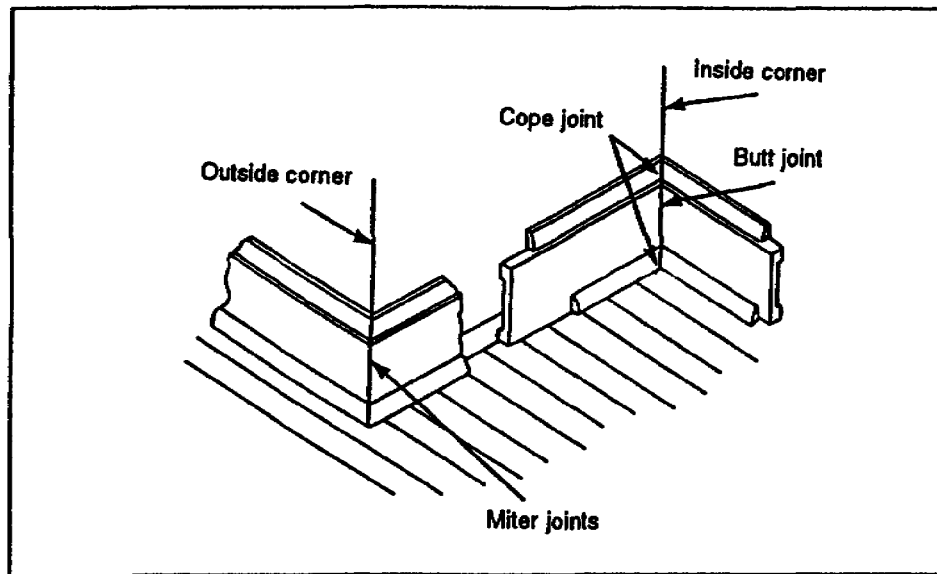


Figure 2-35. One-piece baseboard

a. Square-edged (or two-piece) baseboard consists of a square-edged baseboard topped with a small base cap. When the wall covering is not straight and true, small base molding will conform more closely to the variations than will a one-piece base alone. This type of baseboard is usually 5/8 by 3 1/4 inches or wider. Install square-edged baseboard with a butt-joint at the inside corners and a mitered joint at the outside corners (see Figure 2-36, page 2-26).



**Figure 2-36. Square-edged baseboard**

b. Narrow- and wide-ranch base (one-piece baseboard) are  $\frac{3}{4}$  by  $3 \frac{1}{4}$  inches or wider and vary from  $\frac{1}{2}$  by  $2 \frac{1}{4}$  inches to  $\frac{1}{2}$  by  $3 \frac{1}{4}$  inches or wider.

c. A wood member at the junction of the wall and carpeting serves as a protective bumper; however, wood trim is sometimes eliminated. Most baseboards are finished with a  $\frac{1}{2}$ - by  $\frac{3}{4}$ -inch base shoe. A single-base molding without the shoe is sometimes placed at the wall-floor junction, especially where carpeting might be used.

d. Baseboard should be installed with a butt joint at the inside corners and a mitered joint at the outside corners. It should be nailed to each stud with two 8d finishing nails. Base molding should have a coped joint at inside corners and a mitered joint at outside corners. A coped joint is one in which the first piece is square cut against the plaster or base and the second molding is coped. This is done by sawing a  $45^\circ$  miter along the inner line of the miter. The base shoe should be nailed into the subfloor with long, slender nails, but not into the baseboard itself. Then, if there is a small amount of movement in the floor, no opening will occur under the shoe. When several pieces of molding are needed, they should be joined with a lap miter. When the face of the base shoe projects beyond the face of the molding, it abuts.

## **PART D - STAIRS**

The most critical factor in stair design is the relationship between the rise (riser) and run (tread). A unit rise of 7 inches to  $7 \frac{5}{8}$  inches high with an appropriate tread will combine both comfort and safety. Although you will often find service

stairs steeper, the riser should not exceed 8 inches. To make the stairs steeper, increase the rise and shorten the run (see Figure 2-37).

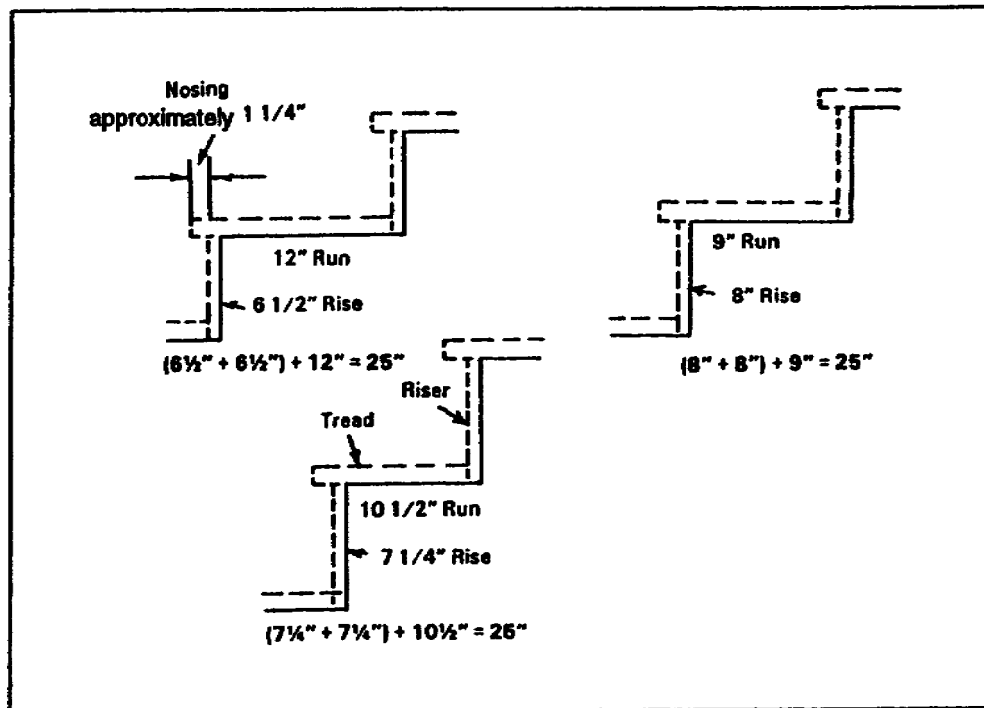


Figure 2-37. Stair design

**2-17. Stair Design.** Use the following rules when designing stairways:

Rule 1. The sum of 2 risers and 1 tread should equal 25 inches.

Rule 2. The sum of 1 riser and 1 tread should equal 17 to 19 inches.

Rule 3. The height of the riser, multiplied by the width of the tread, should equal approximately 75 inches. According to rule 1, a riser of 7 1/2 inches would require a tread of 10 inches. A 6 1/2-inch riser would require a 12-inch tread.

**2-18. Stairway Calculations.** To calculate the number and size of risers and treads for a given run, first divide the total rise by 7. If the total rise for a stairway is 7 feet 10 inches or 94 inches, the answer will be 13.43. Since there must be a whole number for risers, select the one closest to 13.43 (13) and divide it into the total rise.

94 inches divided by 13 = 7.23 or 7 1/4 inches

Number of riser = 13

Riser height = 7 1/4 inches

In a given stair run (see Figure 2-38), the number of treads will be one less than the number of risers. A 10 1/2-inch tread will be correct for the following example, and the total run would be calculated as follows:

Number of treads = 12

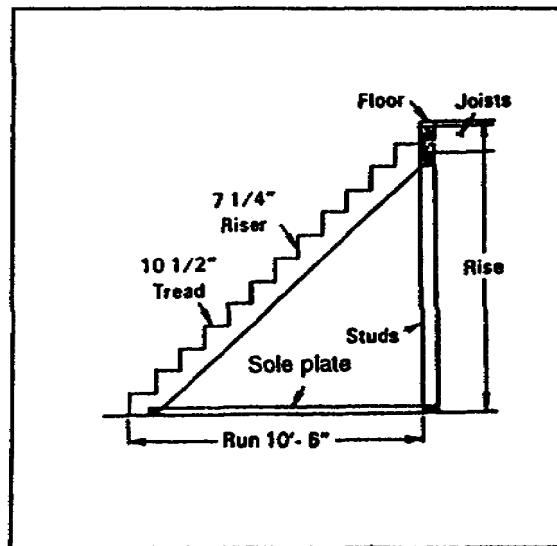
Total run = 10 1/2 inches x 12 treads = 126 inches or 10 feet 6 inches

The stairs will have--

13 risers each, 7 1/4 inches high.

12 treads each, 10 1/2 inches wide.

A total run of 10 feet and 6 inches.



**Figure 2-38. Stair run**

**2-19. Stairway Frames.** To frame simple, straight, string stairs--

a. Take a narrow piece of straight stock, called a story pole, and mark on it the distance from the lower-floor to the upper-floor level. This is the lower-room height, plus the thickness of the floor joists and the rough and finished flooring. It is also the total rise of the stairs. Keep in mind that a flight of stairs forms a right triangle. The rise is the height of the triangle, the run is the base, and the length of the stringers is the hypotenuse.

b. Set dividers at 7 inches, the average distance from one step to another.

c. Step off this distance on the story pole.

d. Adjust the divider span slightly if this distance will not divide evenly into the length of the story pole. Step off this distance again.

e. Continue this adjusting and stepping off until the story pole is marked off evenly. The span of the dividers must be near 7 inches. This represents the rise of each step.

f. Count the number of spaces stepped off evenly by the dividers on the story pole. This will be the total number of risers on the stairs.

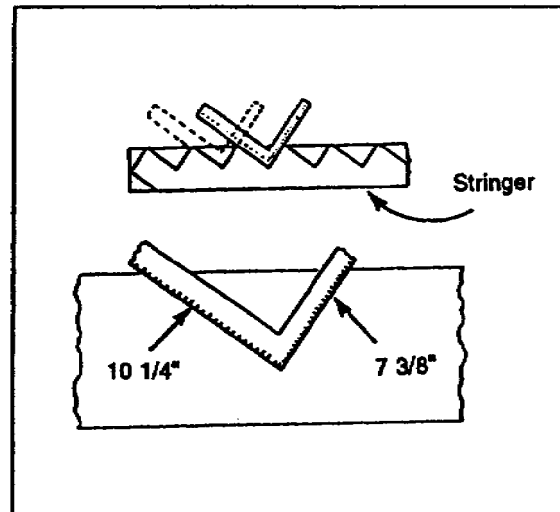
g. Measure the length of the stairwell opening for the length of the run of the stairs. Obtain this length from the plans. The stairwell-opening length forms the base of a right triangle. The height and base of the triangle have now been obtained.

**2-20. Stairway Dimensions.** Standard procedures can be used to determine the height of the rise, the length of the stairway, and the width of tread.

a. **Rise Height.** In order to determine the height of the risers, use a set of dividers and set them at 7 inches. Now step off the distance on the story pole from one end of the pole to the mark you made on the other end. If the distance will not divide into the length of the story pole evenly, adjust the divider spans slightly and again step off this distance on the story pole. Continue adjusting and stepping off until the story pole is marked off evenly. Now count the number of spaces stepped off. This will be the total number of risers in the stairs.

b. **Stairway Length.** Measure the length of the stairwell for the length of the run of stairs. The length may also be obtained from the details on the pane.

c. **Tread Width.** To determine the width of each tread, divide the number risers, less one (remember there is one more riser than thread), into the run stairs. The numbers obtained are to be used on the steel square in laying off the run and rise of each tread and riser on the stringer (see Figure 2-39).



**Figure 2-39. Laying off run and rise**

- Locate the width of the tread and the height of the riser on the steel framing square.
- Use these figures to lay off the tread and riser of each step on the stringer equal to the number of risers previously obtained by dividing the story pole into equal spaces. Your stringer is now ready to be cut.

## LESSON 2

### PRACTICE EXERCISE

The following items will test your grasp of the material covered this lesson. There is only one correct answer to each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. When can siding be placed before door and window casings are set in place?
  - A. On hasty construction
  - B. When sheathing is not used
  - C. Only when plywood is used
  - D. When studs are 24 inches on center
2. Where do you center joints when hanging sheetrock?
  - A. On girts
  - B. On joints
  - C. On studs
  - D. On T-posts
3. What purpose does molding serve at the junction of a wall and the floor?
  - A. As a bumper
  - B. As a decoration
  - C. As an extension
  - D. As a support
4. What type of bracing is placed between the studs in short blocks?
  - A. Corner
  - B. Cut-in
  - C. Let-in
  - D. Diagonal

5. What type of sheathing can be used to omit some types of bracing?
- A. Diagonal board
  - B. Horizontal board
  - C. Building paper
  - D. Plywood
6. When using a story pole to design a flight of stairs, step off the pole the average distance of the risers. You find that this distance will not divide into the height of the stairs evenly. What should you do?
- A. Adjust the distance slightly
  - B. Divide again by the same number
  - C. Measure the pole again
  - D. Use another story pole
7. What type of joint should a square-edged baseboard have at the outside corners?
- A. Dove-tail
  - B. Rabbet
  - C. Half-lap
  - D. Mitered
8. At what point on the wall should you start when nailing diagonal sheathing?
- A. The corners
  - B. The left side
  - C. The right side
  - D. The top
9. In relation to the studs, which direction should the face grain run when using plywood sheathing?
- A. Horizontal
  - B. Diagonal
  - C. Parallel
  - D. Half-lap



10. What is nailed over the cracks between vertical wood siding?
- A. Battens
  - B. Tar paper
  - C. Vertical siding
  - D. Molding

## LESSON 2

### PRACTICE EXERCISE

#### ANSWER KEY AND FEEDBACK

<u>Item</u>	<u>Correct Answer and Feedback</u>
1. B	When sheathing is not used When sheathing is not used . . . (page 2-18, para 2-12b(2))
2. C	On studs Install succeeding sheets . . . (page 2-21, para 2-14(1))
3. A	Bumper Although a wood member . . . (page 2-25, para 2-15)
4. B	Cut-in Cut-in bracing . . . (page 2-28, para 2-4b)
5. D	Plywood If plywood sheathing . . . (page 2-6, para 2-4c)
6. A	Adjust the distance slightly Adjust the divider . . . (page 2-28, para 2-19d)
7. D	Mitered Install square-edge baseboard . . . (page 2-25, par 2-15a)
8. A	Corners If it is to be put . . .(page 2-14, para 2-11a)
9. C	Parallel Install the sheets . . . (page 2-15, para 2-11c)
10. A	Battens The cracks are covered . . . (page 2-17, par 2-12a)

## LESSON 3

### ROOF CONSTRUCTION

Critical Task: 051-236-1144

### OVERVIEW

#### LESSON DESCRIPTION:

At the end of this lesson, you will be able to describe the construction of a roof system.

#### TERMINAL LEARNING OBJECTIVE:

**ACTION:** You will describe how to construct a roof system.

**CONDITION:** You will be given the material contained in this lesson.

**STANDARD:** You will correctly answer the practice exercise questions at the end of this lesson.

**REFERENCES:** The material contained in this lesson was derived from FM 5-426 (Chapter 7).

### INTRODUCTION

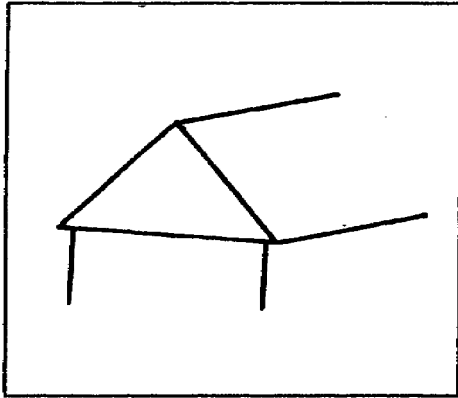
The roof's main purpose is to keep out the rain, cold, or heat. It must be strong enough to withstand high winds sloped to shed water; and, in areas of heavy snow, it must be constructed more rigidly to bear the extra weight.

### PART A - ROOF TYPES

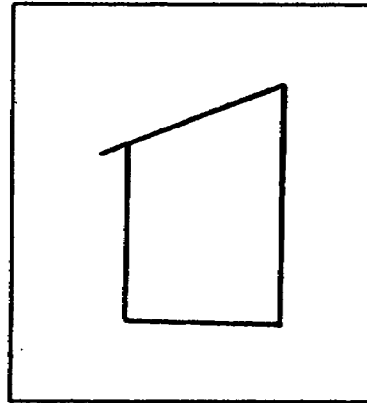
This part will familiarize carpenters with the most common types of roof construction. Roofs for theater of operations construction are chosen to suit the building; the climate; the estimated length of time the building will be used; and the material, time, and skill require for construction.

**3-1. Gable Roof.** This roof has two roof slopes that meet at the center (ridge), forming a gable. It is the most common roof because it is simple, economical, and may be used on any type of structure. Refer to Figure 3-1, page 3-2.

**3-2. Lean-To or Shed Roof.** This roof is used where hasty or temporary construction is needed and where sheds or additions to buildings are erected. The pitch of this roof is in one direction only. The roof is held up by the walls or posts on four sides. One wall, or the posts on one side, is higher than those on the opposite side. Refer for Figure 3-2.



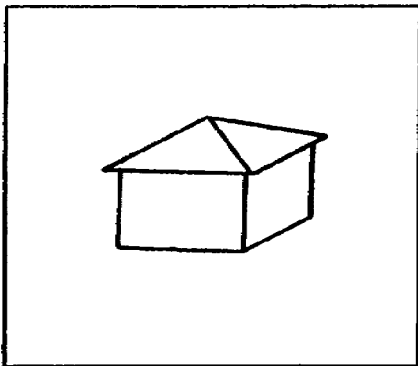
**Figure 3-1. Gable roof**



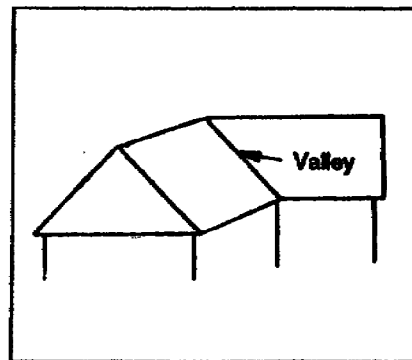
**Figure 3-2. Lean-to or shed roof**

**3-3. Hip Roof.** This roof has four sides or slopes running upward toward the center of the building to create a ridge (or peak). Rafters at the corners run diagonally from the bottom edge to meet at the center (ridge). Other rafters are then framed into them. Refer to Figure 3-3.

**3-4. Valley Roof.** This roof is framed of two intersection hip or gable roofs. The two roofs meet at a valley. Each roof slants in a different direction. This roof is seldom used, since it is complicated and requires much time and labor. Refer to Figure 3-4.



**Figure 3-3. Hip roof**



**Figure 3-4. Valley roof**

## PART B - FRAMING MEMBERS

Joists, rafters, truss, purlins, and braces are considered the main framing members of a roof system.

**3-5. Joists.** Ceiling joists form the framework of the ceiling of the room. They are usually lighter than floor joists but large enough to remain rigid. Ceiling joists are usually installed 16 or 24 inches on center, with the first ceiling joist placed on the outside edge of the top plate. The second joist is placed 16 inches on center lines from the outside edge of the first joist, and the remaining joists are placed 16 inches on the center lines continuing across the building. Extra joists, if needed, may be paced without affecting the spacing of the prime joists. Joists that lie beside rafters on a plate are cut at the same pitch as the rafter, flush with the top of the rafter (see Figure 3-5). The ceiling joists are nailed to both the top plates and the rafters (see Figure 3-6).

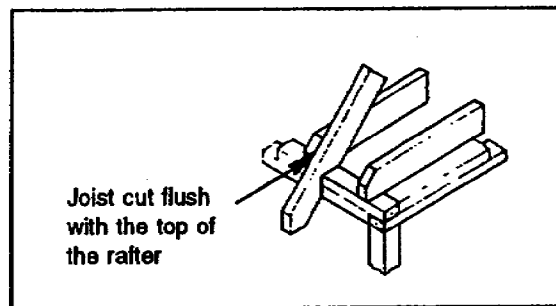


Figure 3-5. Ceiling joists

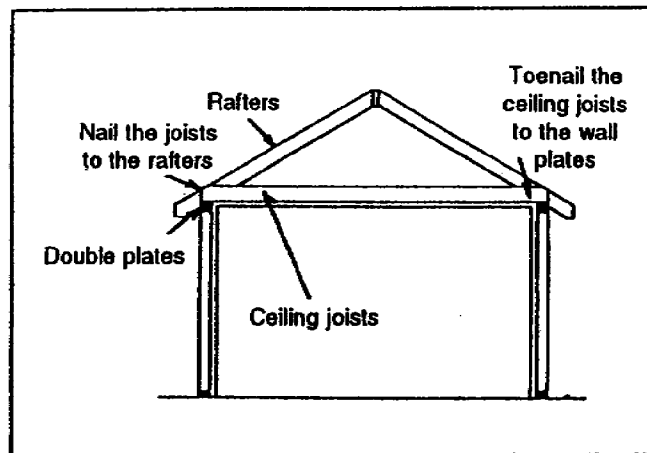
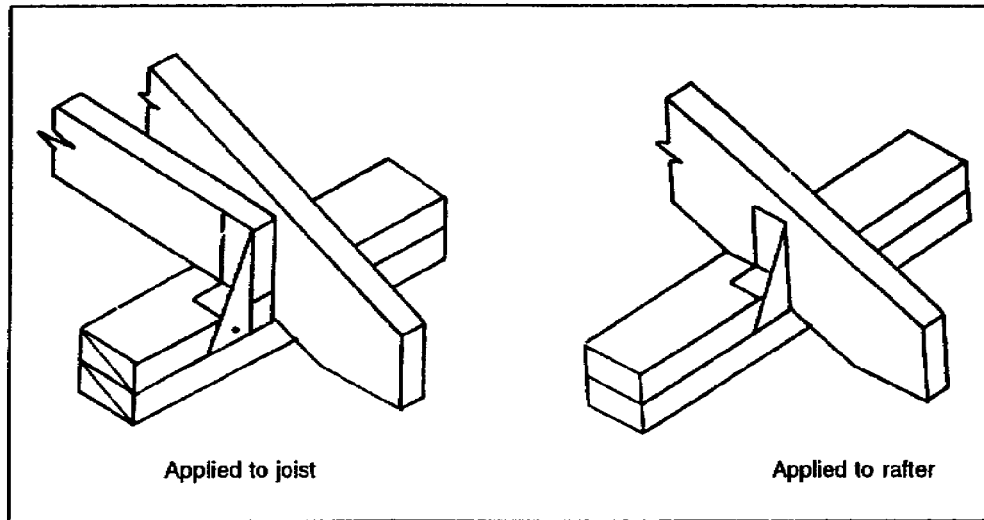


Figure 3-6. Nailing ceiling joists

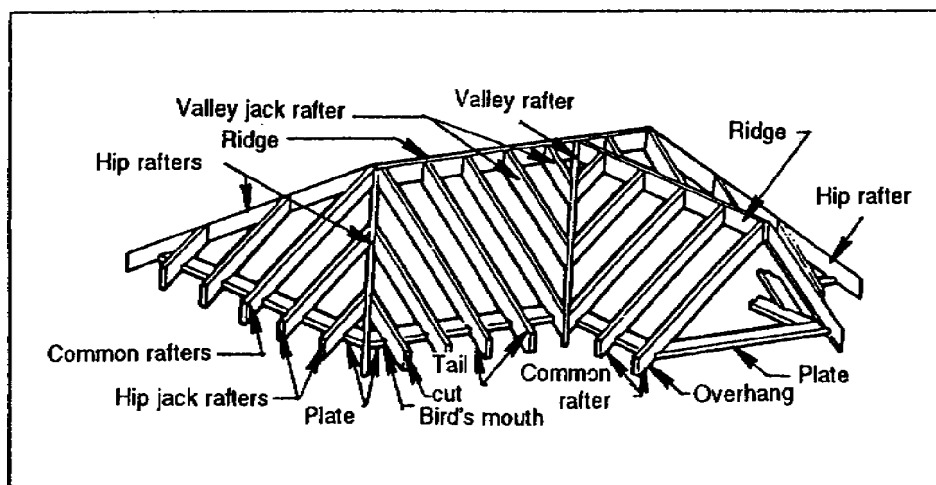
**3-6. Rafters.** Rafters make up the main framework of all roofs. They are inclined members spaced from 16 to 48 inches apart. They vary in size, depending on length and spacing. The tops of inclined rafters are fastened to the ridge or

another rafter, depending on the type of roof. Rafters rest on the top wall plate. Rafters are nailed to the plate, not framed into it. Some are cut to fit the plate, while in hasty construction they are merely laid on top of the plate and nailed in place. They may extend a short distance beyond the wall to form the eaves and protect the sides of the building. Sometimes, metal anchors are used to connect joints and rafters to the top plate (see Figure 3-7). Metal anchors permit rapid installation of joist and rafters, eliminating the need for nailing them. Metal anchors are fastened with 1 1/4 inch nails.



**Figure 3-7. Metal anchors**

a. Types. Examples of most types of rafters are shown in Figure 3-8. The four types of rafters used are common, hip, valley, and jack.



**Figure 3-8. Roof framing terms**

(1) Common rafters. These are framing members that extend at right angles from the plate line to the roof ridge. They are called common rafters because they are common to all types of roofs and are used as the basis for laying out other types of rafters.

(2) Hip rafters. These are roof members that extend diagonally from the corner of the plate to the ridge.

(3) Valley rafters. These rafters extend from the plate to the ridge along the lines where two roofs intersect.

(4) Jack rafters. These are a common rafter. The three kinds of jack rafter are the--

- Hip jack, which extends from the plate to the hip rafter.
- Valley jack, which extends from the ridge of the valley rafter.
- Cripple jack, which is placed between a hip rafter and a valley rafter. The cripple jack rafter is also part of a common rafter, but it touches neither the ridge of the roof nor the rafter plate.

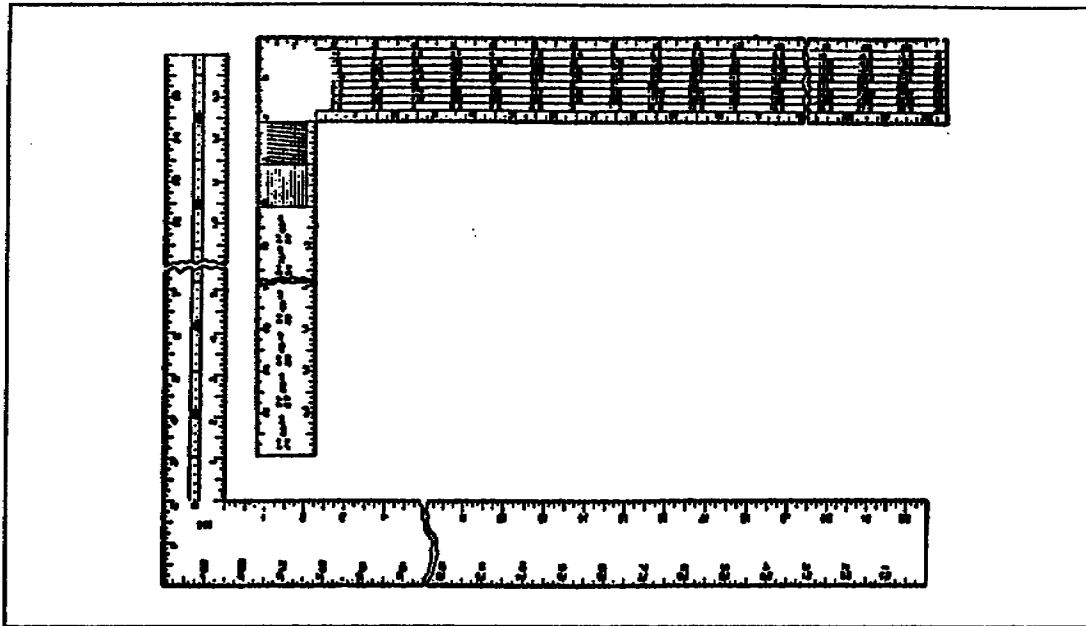
b. Rafter Layout. Rafters must be laid out and cut with the slope, length, and overhang exactly right so that they will fit when placed in the roof.

(1) Scale or Measurement Method. The carpenter should first determine the length of the rafter and the length of the lumber from which the rafter may be cut. If he is working from a roof plan, he learns the rafter lengths and the width of the building from the plan. If no plans are available, the width of the building must be measured.

To determine the rafter length, first find one-half of the distance between the outside plates. (The amount of rise per foot has yet to be considered.) If the building is 20 feet wide, half the span will be 10 feet.

As an example, use a rise per foot of 8 inches. To determine the overall length of a rafter, measure on the steel carpenter's square the distance between 8 on the tongue and 12 on the blade (8 is the rise, and 12 is the unit run). This distance is 14 5/12 inches. This represents the line length of a rafter with a total run of 1 foot and a rise of 8 inches (see Figure 3-9, page 3-6).

Since the run of the rafter is 10 feet, multiply 10 by the line length for 1 foot ( $10 \times 14 \frac{5}{12} = 144 \frac{2}{12}$ ). The answer is 144 2/12 inches or 12 feet 1/6 inch. The amount of overhang, normally 1 foot, must be added if an overhang is to be used. This makes the total length of the rafter 13 feet 1/6 inch. Use a 14-foot timber.

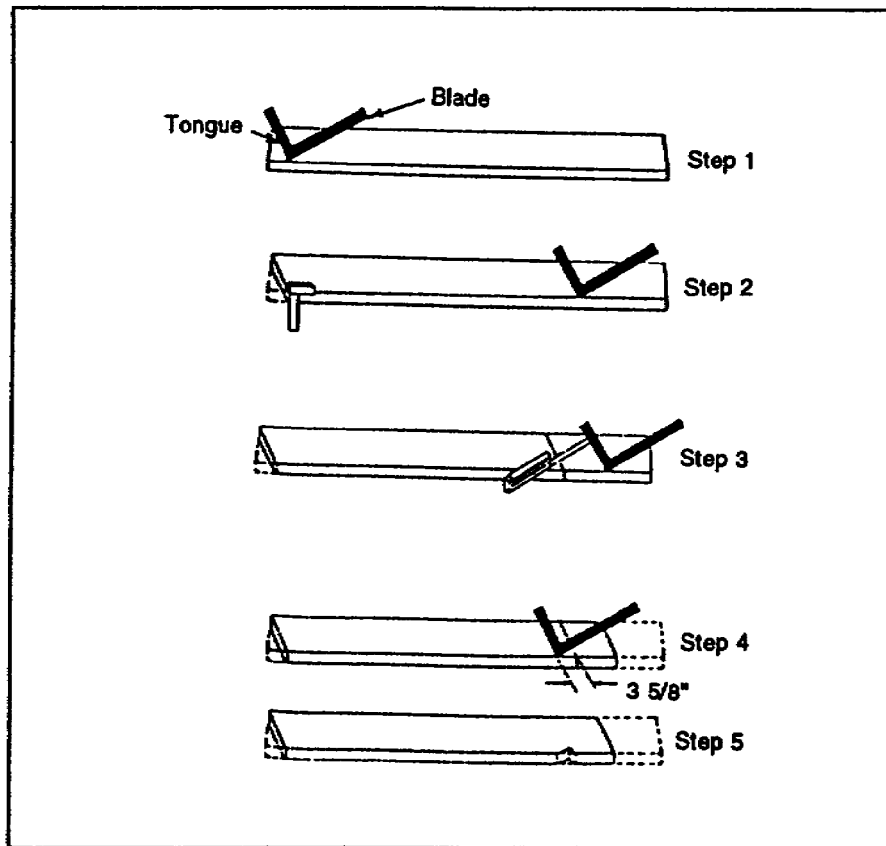


**Figure 3-9. Steel carpenter's square**

(2) Pattern Rafter Method. After the length has been determined, the timber is laid on sawhorses (saw benches) with the crown or bow (if it has any) as the top side of the rafter. If possible, select a straight piece for the pattern rafter. If a straight piece is not available, have the crown toward the person laying out the rafter. Figure 3-10 illustrates the five steps of the pattern rafter method.

- Hold the square with the tongue in the right hand, the blade in the left, and the heel away from the body. Place the square as near the upper end of the rafter a possible.
- In the example, the figure 8 on the tongue and 12 on the blade are placed along the timber edge, that is to be the top edge of the rafter as shown in step 1. Mark along the tongue edge of the square, which will be the plumb cut at the right.
- Since the length of the rafter is known to be 12 feet  $\frac{1}{6}$  inch, measure the distance from the top of the plumb cut and mark it on the timber. Hold the square in the same manner with the 8 mark on the tongue directly over the 12-foot  $\frac{1}{6}$ -inch mark. Mark along the tongue of the square to give the plumb cut for the seat (see step 2).
- Next, measure off perpendicular to this mark, the length of overhang along the timber. Make a plumb-cut mark in the same way, keeping the square on the same edge of the lumber (see step 3). This will be the tail cut of the rafter. Often, the tail cut is made square across the timber.





**Figure 3-10. Rafter method**

- The level cut or width of the seat is the width of the plate, measured perpendicular to the plumb cut, as shown in step 4. Using the try square, square the lines down on the sides from all level and plumb-cut lines. Now the rafter is to be cut (see step 5).

(3) Step-Off Method. The rafter length of any building may be determined by “stepping it off” by successive steps with the square, as follows:

- Step off the same number of steps as there are feet in the run. For example, if a building is 20 feet 8 inches wide, the run of the rafter would be 4 inches over 10 feet. Figure 3-11, page 3-8, illustrates the four steps of the step-off method.
- This 4 inches is taken care of in the same manner as the full-foot run; that is, with the square at the last step position, make a mark on the rafters at the 4-inch mark (see Figure 3-11, step 1).
- With the square held for the same cut as before, make a mark along the tongue. This is the line length of the rafter. The seat cut and hangover are made as described above and shown in Figure 3-11, steps 2, 3, and 4.

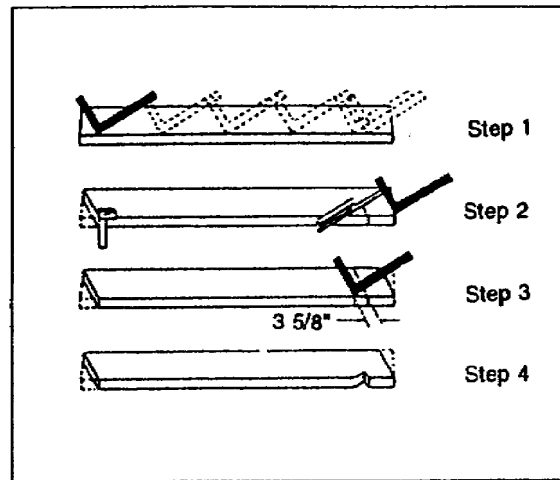


Figure 3-11. Step-off Method

**NOTE:** When laying off rafters by any method, be sure to recheck the work carefully. When two rafters have been cut, it is best to put them in place to see if they fit. Minor adjustments may be made at this time without serious damage or waste of material.

(4) Table Method 1. To use the framing square to lay out rafters, the width of the building must first be known. Suppose the building is 20 feet 8 inches wide, and the rise of the rafters is to be 13 inches per foot of run. The total run of the rafters will be 10 feet 4 inches.

- Look at the first line of figures under the 13-inch mark (see Figure 3-12). You will see the number 17.69. This is the length in inches of a rafter with a run of 1 foot and a rise of 13 inches.

23	22	21	20	16	13	12	
LENGTH OF MAIN RAFTERS PER FOOT RUN				20 00	17 69	12	
LENGTH HIP OR VALLEY RAFTERS PER FOOT RUN				23 36	21 40	12 5/16	
DIFFERENCE IN LENGTH OF JACKS 16 INCHES CENTERS				2 2 5/8	23 5/8	18 3/16	
DIFFERENCE IN LENGTH OF JACKS 2 FEET CENTERS				3 4	2 1 1/2	10 1/4	
SIDE CUT OF JACKS				7 3/16	8 1/8	11 1/16	
SIDE CUT OF HIP OR VALLEY				8 3/4	9 5/8	1 1/16	
22	21	20	19	18	14	11	2

Figure 3-12. Table Method 1

- To find the line length of a rafter with a total run of 10 feet 4 inches, multiply 17.69 inches by  $10 \frac{1}{3}$  and divide by 12 to get the answer in feet ( $17.69 \times 10.333 = 182.79$ ). The total of 182.79 inches is divided by 12 to equal  $15 \frac{3}{12}$  feet. Therefore, 15 feet 3 inches is the line length of the rafter.

(5) Table Method 2. The rafter table is on the back of the blade of some squares. Figure 3-13 shows the run, rise, and pitch of the rafters of the seven most common roof pitches. The figures are based on the length of the horizontal measurement of the building from the center to the outside (run). The rafter table on the outside edge, on the back of the square, gives both the body and the tongue in twelfths. The inch marks on the square may represent inches or feet, and the twelfth marks may represent twelfths of an inch or twelfths of a foot. The rafter table is used in connection with the marks and figures on the outside edge of the square. You will notice that at the left end of the table there are figures representing the run, rise, and the pitch.

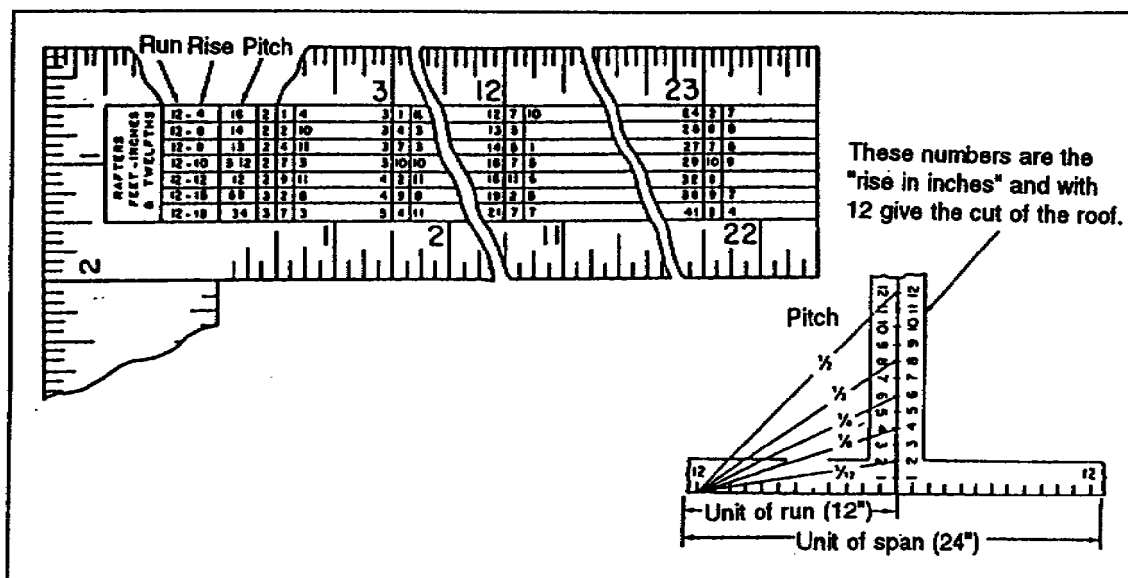


Figure 3-13. Table Method 2

- Run. In the first column, the figures are all 12. These may be used as 12 inches or 12 feet, because they represent the run of 12 inches.
- Rise. The second column of figure represents various rises per foot: 4, 6, 8, 10, 12, 15, and 18.
- Pitch. The third column of figures, in fractions, represents various pitches:  $\frac{1}{6}$ ,  $\frac{1}{4}$ ,  $\frac{1}{3}$ ,  $\frac{5}{12}$ ,  $\frac{1}{2}$ ,  $\frac{5}{8}$ , and  $\frac{3}{4}$  (see Figure 3-14, page 3-10).

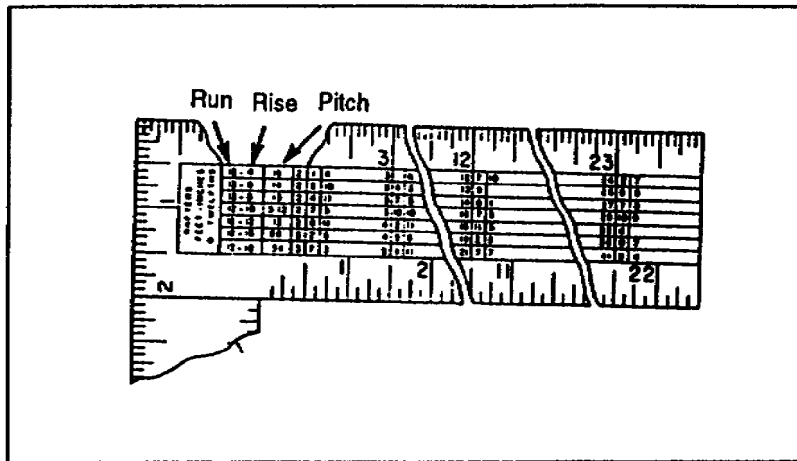


Figure 3-14. Pitch on the rafter table

c. Assembly. Rafters are usually made into trusses. Two rafters are connected at the top, using a collar tie well nailed into both rafters. Before any ties or chords are nailed, the rafters should be spread at the lower end to equal the width of the building. This is done by using a template or by measuring the distance between the seat cuts with a tape (see Figure 3-15).

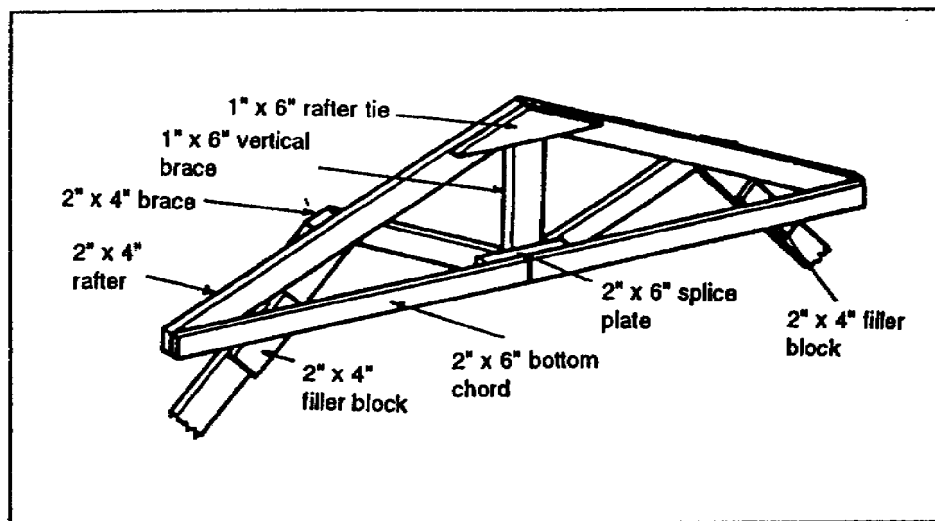


Figure 3-15. Assembling a truss

(1) Chord. A 1 by 6 or 2 by 4 chord is nailed across the rafters at the seat cut to tie them together. This chord forms a truss with the two rafters. A hanger or vertical member of 1 by 6 is nailed to the rafter joint and extends to the chord at midpoint, tying the rafter to the chord.

(2) Collar Beam. A tie or collar beam is a piece of stock (usually 1 by 4, 1 by 6, 1 by 8, or 2 by 4) fastened in a horizontal position to a pair of rafters between the plate and the ridge of the roof. This type of beam tends to keep the building from spreading. Most codes and specifications require them to be 5 feet apart or every third rafter, whichever is less. Collar ties are nailed to common rafters with four 8d nails to each end of a 1-inch tie. If 2-inch material is used for the tie, they are nailed with three 16d nails at each end. This type of bracing is used on small roofs where no ceiling joists are used and the building is not wide enough to require a truss. The lower the collar beam or chord, the better it works.

(3) Support. In small roofs that cover only narrow buildings and in which the rafters are short, there is no need for interior support or bracing. In long spans, the roof would sag in the middle if it were not strengthened in some way. To support long rafters, braces or other types of supports must be installed.

(4) Rafter Support. In wide buildings, where the joists or chords must be spliced and there is no support underneath, the rafter and joists support one another (see Figure 3-16).

d. Knee Brace. If no additional bracing is needed, the truss is set in place on the plates. If additional bracing is needed, a knee brace is nailed to the chord. The knee brace forms a 45° angle with the wall stud. For easier erection, the knee brace may be omitted until the rafter truss is set in place (see Figure 3-16).

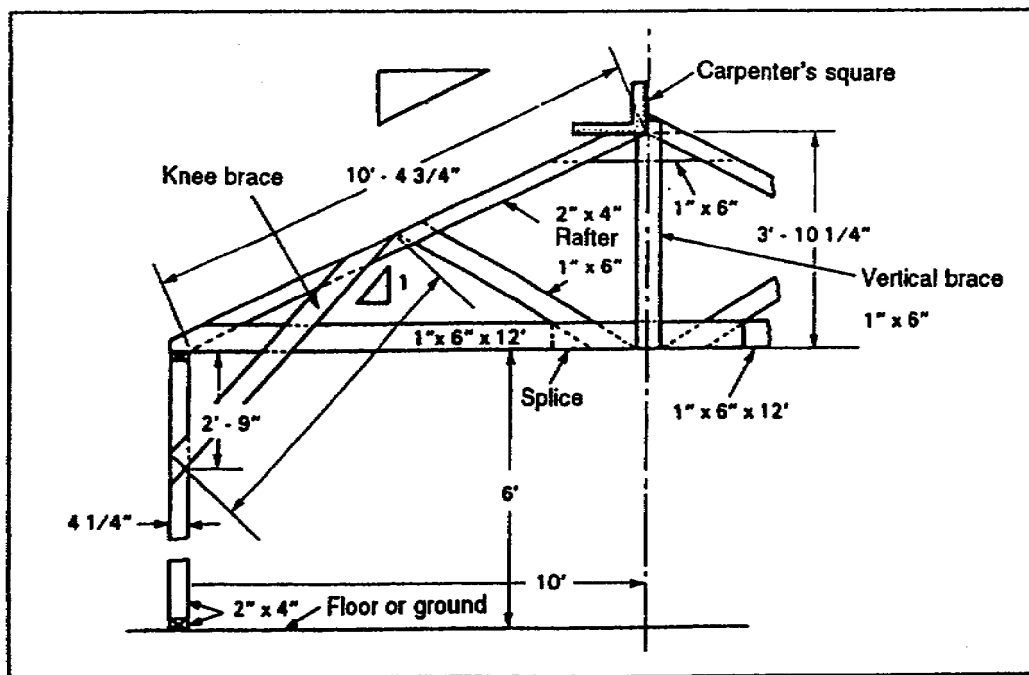


Figure 3-16. Rafter support detail

**3-7. Trusses.** A truss is a framed or jointed structure composed of straight members connected only at their intersections in such a way that if loads are

applied at these intersections, the stress in each member is in the direction of its length. Straight, sound timber should be used in trusses. Figure 3-17 shows various types of trusses used in construction. (The Howe and Fink trusses are most commonly used.) Trusses are used for large spans to give wide, unobstructed floor space for such large buildings as shops and hangars. Sometimes small buildings are trussed to save material. These small trusses act as rafters and give the roof rigidity.

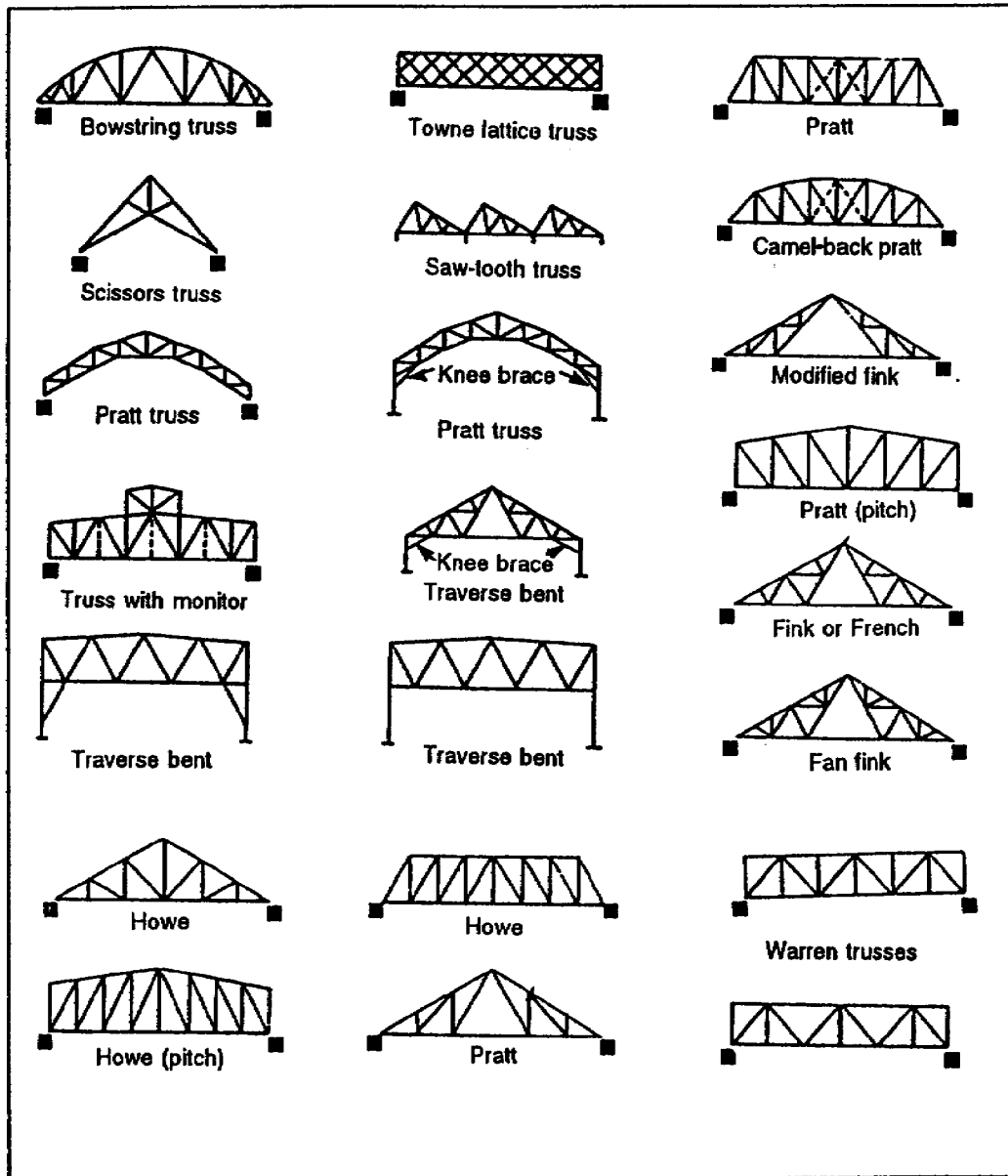
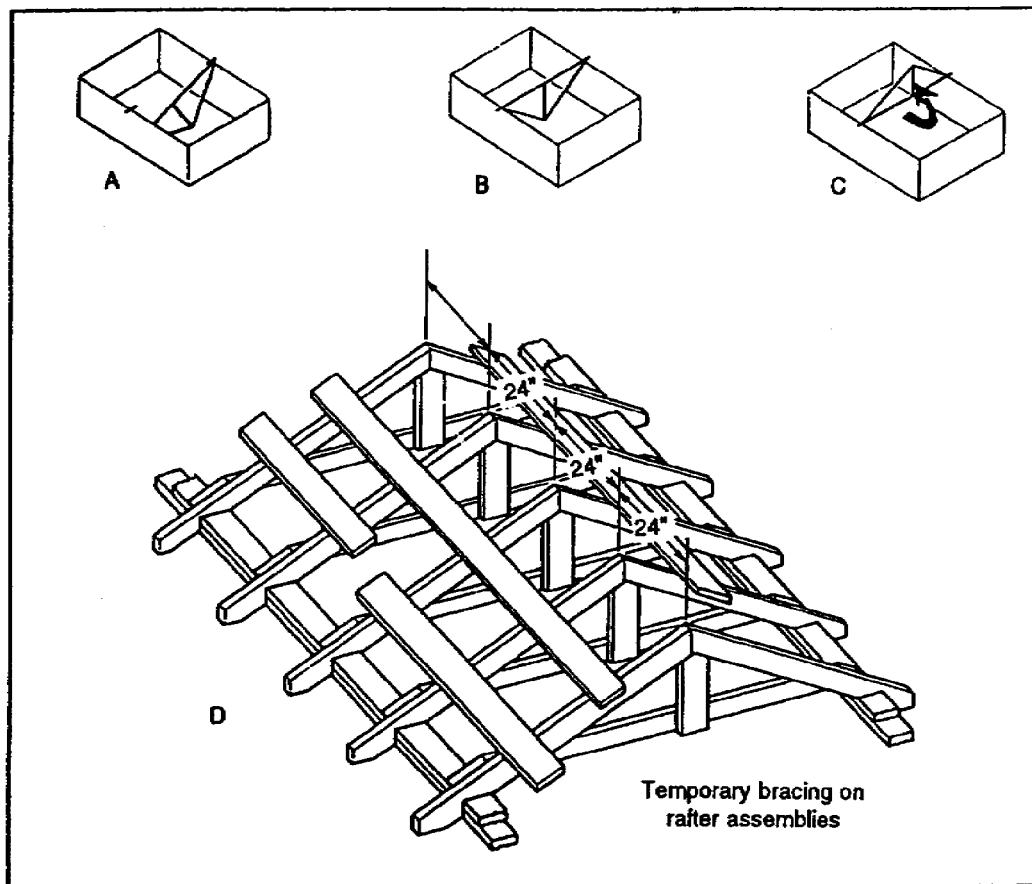


Figure 3-17. Types of trusses

a. Placement. After the rafters have been assembled into trusses, they must be placed on the building (see Figure 3-18). Assemble the first set of rafters in the end section of the building or at the center. Raise rafter trusses into position by hand and nail them into place with 16d nails. (Temporary workbenches may be built for the workers to stand on while erecting trusses.) These trusses must be temporarily braced at the end section of the building until the sheathing is applied. Knee braces are not used on every rafter truss unless needed. Install trusses as follows:



**Figure 3-18. Installing trusses**

- (1) Mark the proper positions of all truss assemblies on the top plate. The marks must show the exact position on the face of all rafters (such as south or north) (see Figure 3-18, A).
- (2) Rest one end of a truss assembly, peak down, on an appropriate mark on the top plate on one end of the structure (see Figure 3-18, A).
- (3) Rest the other end of the truss on the corresponding mark of the top plate on the other side of the structure (see Figure 3-18, B).

(4) Rotate the assembly into position using a pole or rope (see Figure 3-18, C, page 3-13).

(5) Line up and secure the rafter faces flush against the marks.

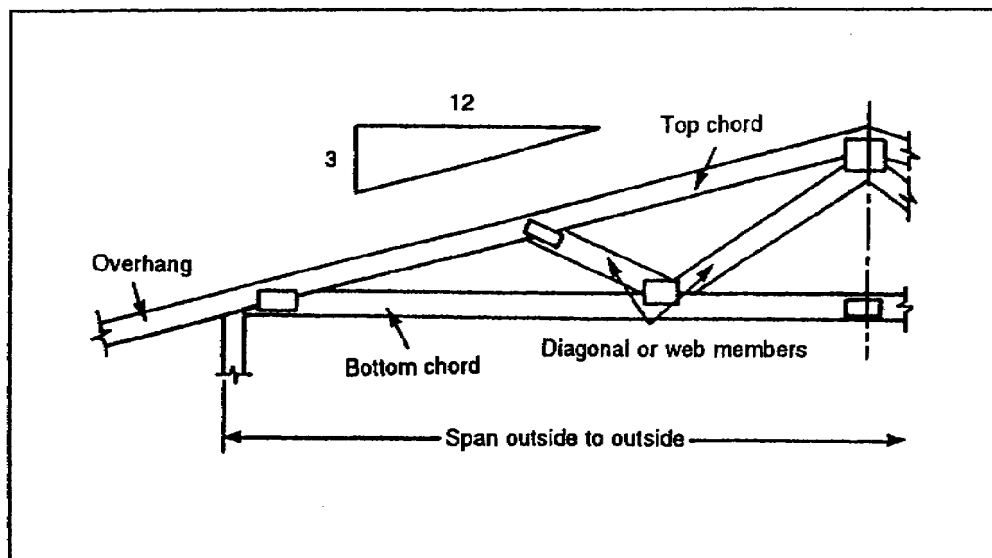
(6) Raise, align, and nail the three assemblies into position. Nail temporary 1 x 6 braces across these three assemblies. Repeat this procedure with the other assemblies as they are brought into position (see Figure 3-18, D). Check the rafter spacing at the peaks as the braces are nailed on.

(7) Braces may be used as a platform when raising those trusses for which there is not enough room to permit rotation.

b. Web Members. The web members of a truss divide it into triangles. The members indicated by heavy lines normally carry tensile stresses for vertical loads. Sometimes the top chords of these trusses slope slightly in one or two directions for roof drainage, but this does not change the type of truss. The necessary number of subdivisions, or panels, depends on the length of the span and the type of construction.

c. Terms. These terms should be understood before proceeding further with this lesson.

(1) Bottom chord. A member that forms the lower boundary of the truss (see Figure 3-19).

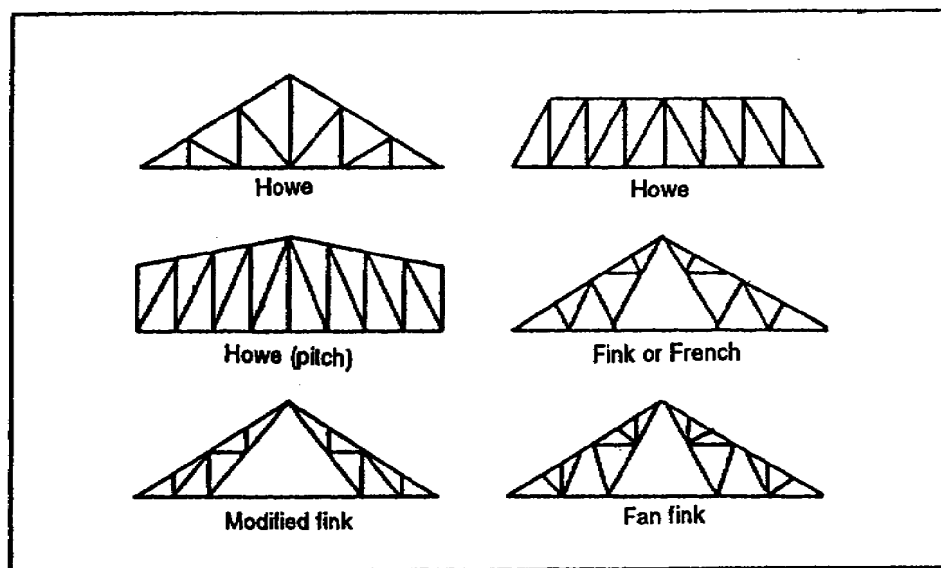


**Figure 3-19. Truss**

(2) Top chord. A member which forms the upper boundary of the truss.

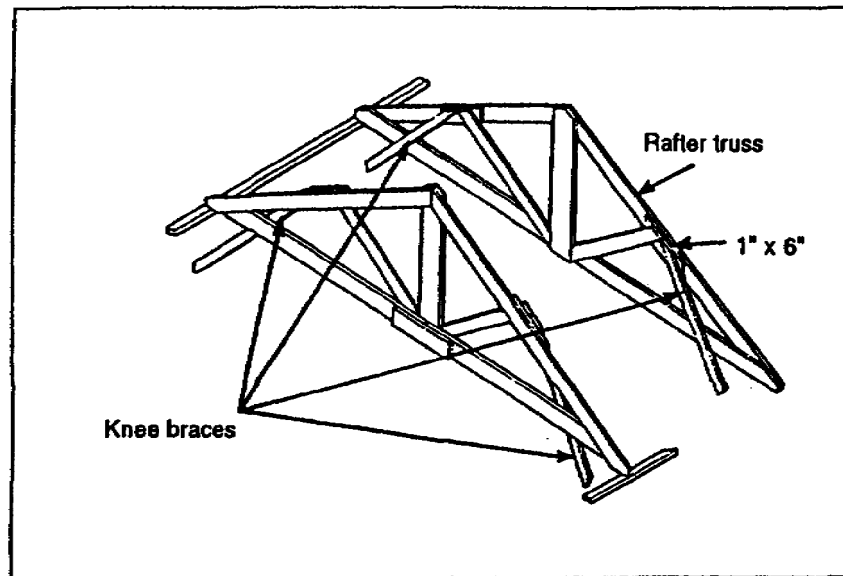


- (3) Chord member. A member that forms part of either the top or the bottom chord.
  - (4) Member. The component that lies between any adjacent joints of a truss. It can be of one or more pieces of structural material.
  - (5) Web member. A member that lies between the top and bottom chords.
  - (6) Joint. Any point in a truss where two or more members meet; sometimes called a panel point
  - (7) Panel length. The distance between any two consecutive joint centers in either the top or bottom chords.
  - (8) Pitch. The ratio of the height of the truss to the span's length.
  - (9) Height of Truss. The vertical distance at midspan from the joint center at the ridge of a pitched truss or from the centerline of the top chord of a flat truss to the centerline of the bottom chord.
  - (10) Span length. The horizontal distance between the centers of the two joints located at the extreme ends of the truss.
- d. Uses. Trusses are used for large spans to give wide, unobstructed floor space for such large building as shops and hangers. The Howe and Fink trusses are most commonly used (see Figure 3-20).



**Figure 3-20. Howe and Fink trusses**

e. Support. Trusses are supported by bearing walls, posts, or other trusses. To brace a truss to a wall or post, knee braces are used as shown in Figure 3-21. These braces tend to make a truss of the entire building by tying the wall to the roof (see Figure 3-21).



**Figure 3-21. Knee braces**

f. Layout. Use the following steps to lay out a truss:

- (1) Build the truss on workbenches that are paced on a level spot on the ground.
- (2) Obtain the measurement of all material from the blueprints.
- (3) Lay the pieces in their correct position to form a truss.
- (4) Nail them together temporarily (see Figure 3-22).
- (5) Lay out the location of all holes to be bored.
- (6) Bore the holes to the size called for on the blueprint.
- (7) Dismantle the truss and withdraw the nails after the holes have been bored.

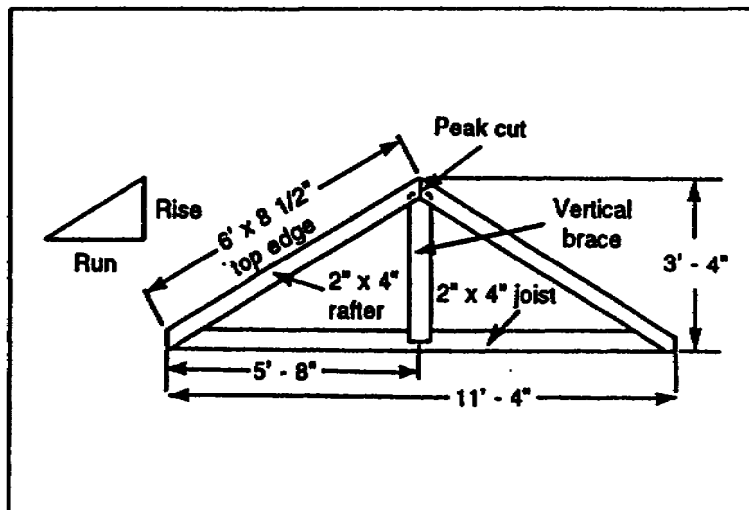


Figure 3-22. Truss layout

g. Assembly. Assembling a truss after it has been cut and bored is simple. In most cases, *timber connectors* are used where different members of the truss join. Assemble the truss with the split rings in place. The bolts are then placed in the holes and tightened. Place washers at the head and nut ends of each bolt. Use straight, sound timber trusses (see Figure 3-23).

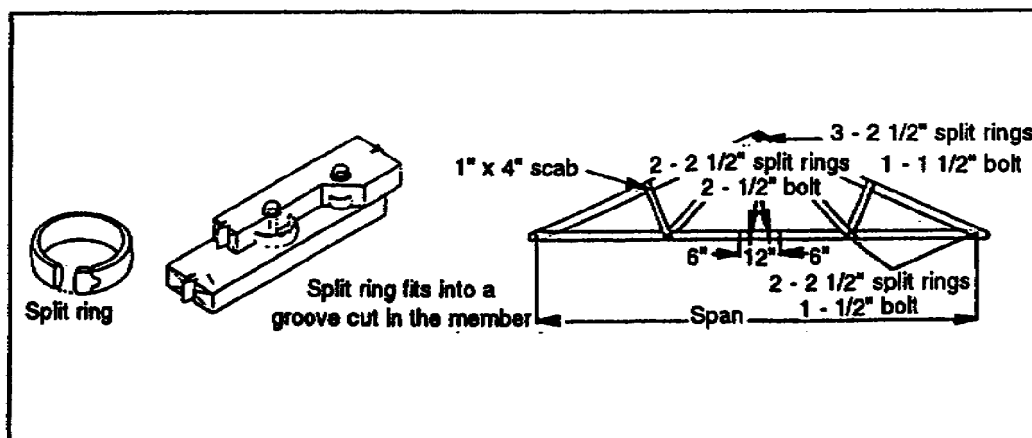
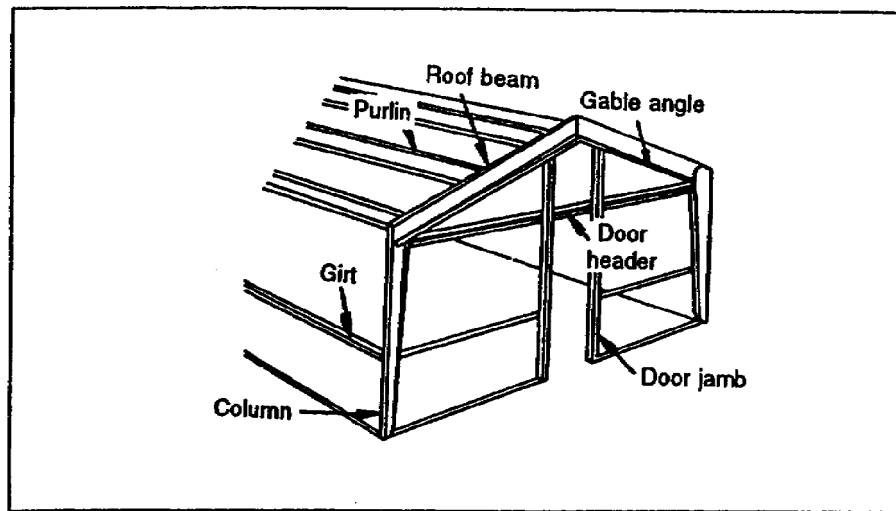


Figure 3-23. Split rings on a truss

**3-8. Purlins.** Purlins are used in roof construction to support corrugated sheet metal if it is used or to support the sheathing of roofs framed with trusses. In small roofs, short purlins are inserted between the rafters and nailed through the rafters. In large buildings where heavy trusses are used, the purlins are continuous members that rest on the trusses and support the sheathing. In small buildings, such as barracks, mess halls, and small warehouses, 2 by 4s are used for purlins, with the narrow side up (see Figure 3-24, page 3-18).



**Figure 3-24. Purlins**

**3-9. Braces.** Bracing is used to stiffen framed construction and make it rigid. Bracing may be used to resist winds, storms, twists, or strains. Good bracing keeps corners square and plumb. Bracing prevents warping, sagging, and shifting that could otherwise distort the frame and cause cracked plaster and badly fitting doors and windows. In small roofs that cover narrow buildings and in which the rafters are short, there is no need for interior support or bracing. In long spans, the roof would sag in the middle if it were not strengthened in some way. To support long rafter, braces or other types of supports must be installed. The three methods commonly used to brace frame structures are let-in, cut-in, and diagonal-sheathing bracings.

a. **Let-In Bracing.** Let-in bracing is set into the edges of studs, flush with the surface. The studs are always cut to let in the braces; the braces are never cut. Use 1 by 4s or 1 by 6s set diagonally from top plates to sole plates, or between top or sole plates and framing studs.

b. **Cut-In Bracing.** Cut-in bracing is toenailed between studs. It usually consists of 2 x 4s cut at an angle to permit toenailing. They are inserted in diagonal progression between studs running up and down from corner posts to the sill or plates.

c. **Diagonal-Sheathing Bracing.** The strongest type of bracing is diagonal sheathing. Each board braces the wall. If plywood sheathing 5/8 inch thick or more is used, other methods of bracing may be omitted.

**3-10. Roofing Terms.** When framing a roof carpenters must be familiar with commonly used roofing terms. The following are the most common of those terms:

a. **Basic Triangle.** The basic triangle is the most elementary tool used in roof framing (see Figure 3-25). When framing a roof, the basic right triangle is formed by the horizontal lines (or run), the rise (or altitude), and the length of the

rafter (the hypotenuse). Any part of the triangle can be computed if the other two parts are known. Use the following equation:

The square of the hypotenuse of a right triangle is equal to the sum of the squares of the two sides. In roofing terms--

$$\text{Rafter length}^2 = \text{run}^2 + \text{rise}^2$$

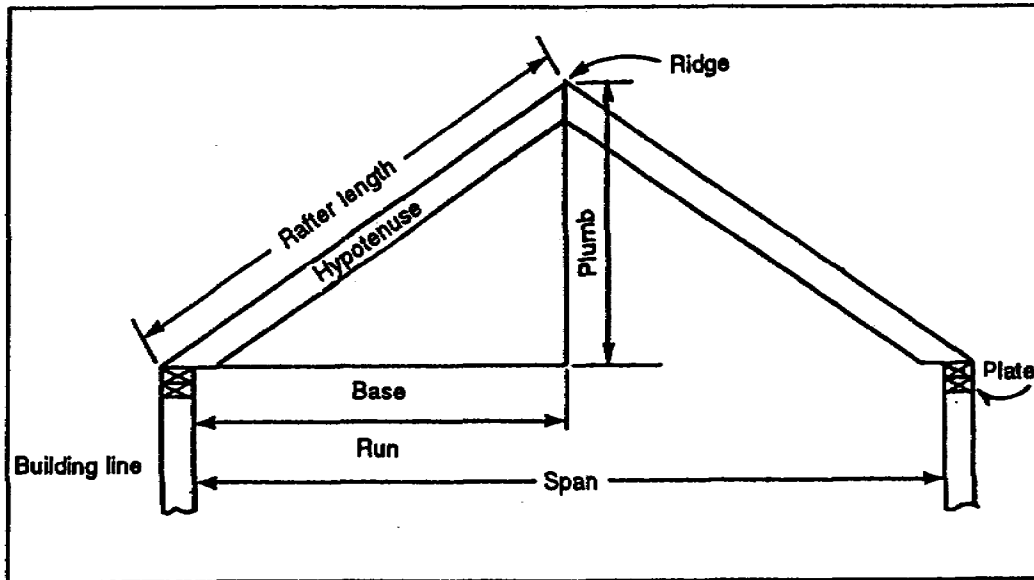


Figure 3-25. Basic triangle

b. Bird's Mouth. A bird's mouth is a cutout near the bottom of a rafter, that fits over the top plate. The cut that fits the top of the plate is called the *seat*; the cut for the side of the plate is called the *heel* (see Figure 3-26).

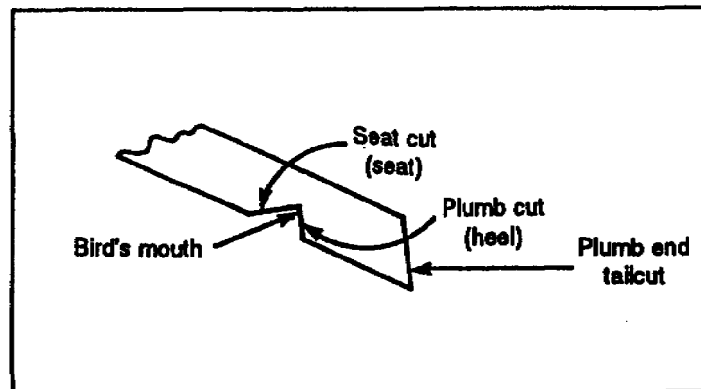


Figure 3-26. Bird's mouth

c. Cut of a Roof. The cut of a roof is the rise over the run (such as 4/12 roof) or the pitch of the roof (see Figure 3-27).

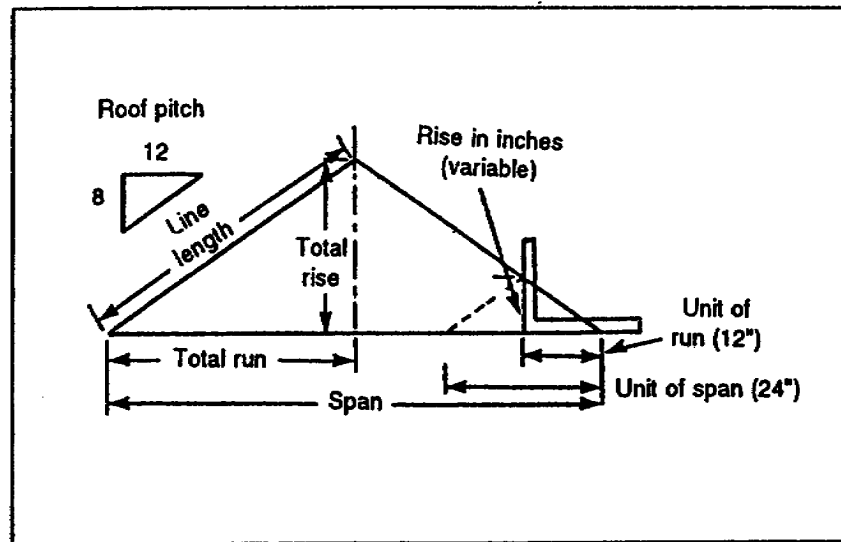


Figure 3-27. Roofing terms

d. Span of a Roof. The span of any roof is the shortest distance between the two opposite rafters' seats (see Figure 3-27).

e. Line Length. In roof framing, line length is the hypotenuse of a triangle whose base is the run and whose altitude is the total rise (see Figure 3-27).

f. Horizontal Line. A horizontal line is one level with the building foundation.

g. Overhang. The overhang is that part of a rafter that extends past the outside edge of the walls of a building. When laying out a rafter, this portion is in addition to the length of a rafter and is figured separately. The overhang is often referred to as the *tailpiece*.

h. Total Rise. The total rise is the vertical distance from the wall plate to the top of the ridge.

i. Run. Run always refers to the level distance any rafter covers—normally, one-half the span.

j. Unit of Run (or unit of measurement). The unit of measurement, 1 foot (or 12 inches), is the same for the roof as for any other part of the building. Using this common unit of measurement, the framing square is used in laying out large roofs.

k. Pitch. Pitch signifies the amount that a roof slants and the ratio of rise (in inches) to run (in inches). Using this method, 4, 6, or 8 inches of rise per foot of

run would give a pitch of 4:12, 6:12, or 8:12. There are two methods of indicating pith.

(1) Method 1. The pitch is indicated as a ratio of the rise to the span of a roof, stated in fractions ( $3/4$ ,  $5/8$ ,  $1/2$ , and  $5/12$ ). The units of span and rise must be the same (inches or feet), and the faction is reduced to its lowest common denominator (see Figure 3-11, page 3-8).

- To obtain the unit rise, multiply the pitch by 24. For example, if the pitch is given as  $1/3$ , multiply  $1/3$  by 24 ( $1/3 \times 24 = 8$ ). Therefore, the unit rise is 8 inches per foot (8-12 pitch).
- If the pitch is given as  $5/12$ , multiply  $5/12$  by 24 ( $5/12 \times 24 = 10$ ). Therefore, the unit rise is 10 inches per foot (10-12 pitch).

(2) Method 2. The pitch is stated as the ratio of rise (in inches) per 1 foot of run (12 inches). Using this method, 4, 6, or 8 inches of rise per foot of run would give a pitch of 4-12, 6-12, or 8-12. A roof with  $1/2$  pitch can be said to have a 12-12 pitch. Remember  $1/2 \times 24 = 12$ .

l. Rise. The rise of a rafter is the vertical (or plumb) distance that a rafter extends upward from the plate.

m. Plumb Line. The line is the line formed by the cord on which the plumb bob is hung (see Figure 3-28).

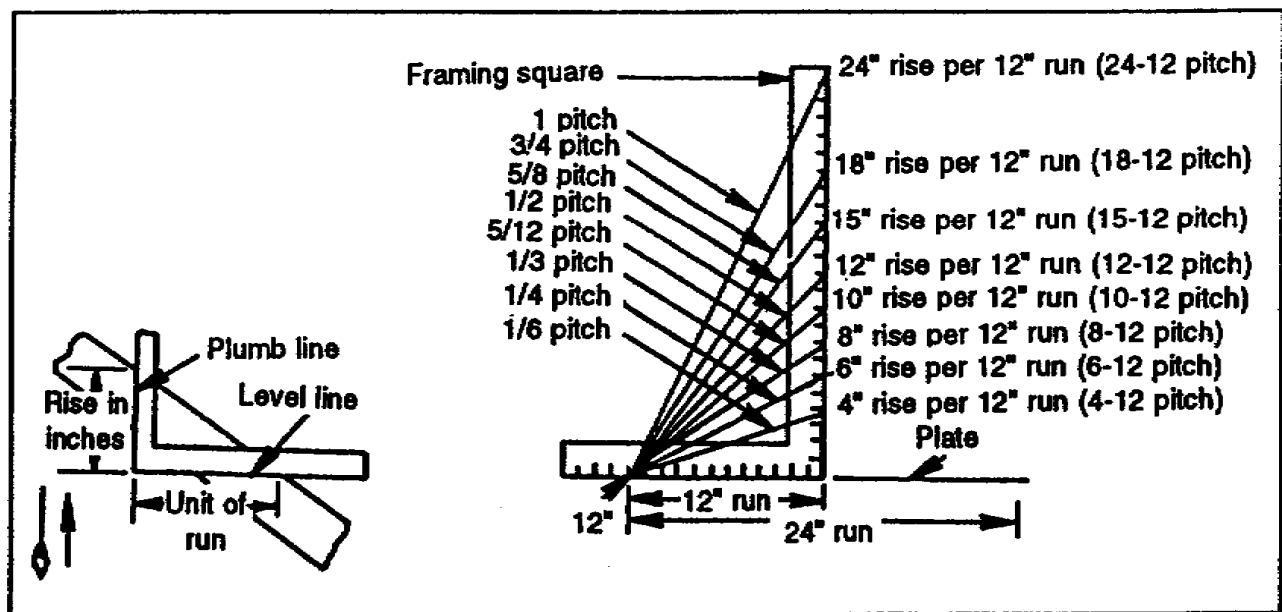


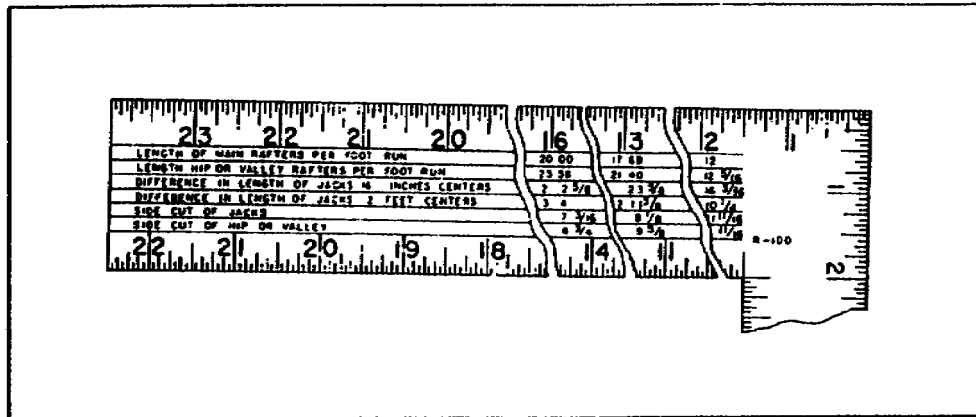
Figure 3-28. Roof pitch

n. Plate. The plate is the wall-framing member that rests on the top of the wall studs (see Figure 3-8, page 3-4).

o. Ridge. The ridge is the highest horizontal roof member. It ties the rafters together at the upper end (see Figure 3-8).

**3-11. Rafter Tables on a Framing Square.** The framing square may have one or two types of rafter tables on the blade. One type gives both the line length of any pitch of rafter per foot of run and the line length of any hip or valley rafter per foot of run. The difference in the length of the jack rafter, spaced 16 or 24 inches (on center), is also shown in the table. Where the jack, hip, or valley rafter needs side cuts, the cut is given in the table. The other type of rafter table gives the actual length of a rafter for a given pitch and span.

a. Line length. The rafter table (see Figure 3-29) is used to determine the length of the common, valley, hip, and jack rafters, and the angles at which they must be cut to fit at the ridge and plate. To use the table, the carpenter must know what each figure represents.



**Figure 3-29. Line lengths on the rafter table**

(1) The row of figures in the first line represents the length of common rafters per foot of run (look at the left end of Figure 3-29), as the title at the left-hand end of the blade indicates.

(2) Each set of figures under each inch division mark represents the length of a rafter per foot of run, with a rise corresponding to the number of inches over the number. For example, under the 16-inch mark appears the number 20.00 inches. This number equals the length of a rafter with a run of 12 inches and a rise of 16 inches. Under the 13-inch mark appears the number 17.69 inches, which is the rafter length for a 12-inch run and a 13-inch rise.

**NOTE: The other five lines of figures in the table are seldom used in the theater of operations.**

b. Actual Length. At the left end of the table (see Figure 3-30) are figures representing the run, rise, and the pitch of a roof

(1) The figures show that a rafter with a run of 12 and a rise of 4 has  $1/6$  pitch. A 12 run, 6-inch rise has  $1/4$  pitch. A 12 run, 8-inch rise has  $1/3$  pitch.



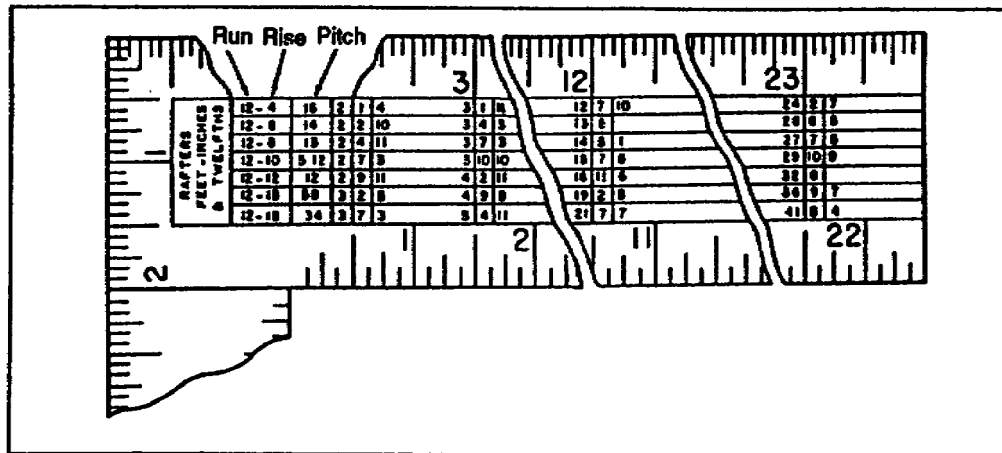


Figure 3-30. Actual lengths on the rafter table

(2) To use the rafter table to determine the length of a rafter with a  $1/6$  pitch (or a rise of  $1/6$  the width of the building) and a run of 12 feet, find the  $1/6$  in the table, then follow the same line of figures to the right until directly beneath the figure 12. The numbers that appear beneath this figure are 12, 7, and 10, which show the rafter length required and which represent 12 feet, 7 inches, and 10/12 of an inch. Therefore, the length of the rafter required is 12 feet 7  $10/12$  inches long.

(3) Using rafter table method 2, assume you have a roof with a  $1/2$  pitch (or a rise of  $1/2$  the width of the building) and a run of 12 feet (see Figure 3-30). Find  $1/2$  pitch on the table. Follow the same line of figures to the right until directly beneath the figure 12. The numbers that appear beneath this figure are 16, 11, and 6, which represents 16 feet 11  $6/12$  inches. The length of the rafter required is 16 feet 11  $6/12$  inches long.

(4) When the run is in inches, the rafter table reads inches and twelfths instead of feet and inches. If the pitch is  $1/2$  and the run is 12 feet 4 inches, add the rafter length of a 12-foot run to that of a rafter length of 4-inch run (see Figure 3-30). For a run of 12 feet and  $1/2$  pitch, the length is 16 feet 11  $6/12$  inches. For a run of 12 feet and  $1/2$  pitch, the length is 5, 7, and 11. In this case, the 5 is inches, the 7 is twelfths, and the 11 is  $11/12$  of  $1/12$  (which is nearly  $1/12$  of an inch). Add the  $1/12$  to the 7 to make it 8, making a total of 5  $8/12$  inches. Add the two lengths together (16 feet 11  $6/12$  inches + 5  $8/12$  inches = 17 feet 5  $1/12$  inches)

(5) If the run of a building is over 23 feet, the table is used as follows: Using a run of 27 feet, with a  $1/4$  pitch (the framing square blade is 24 inches long), find the length for 23 feet, then find the length for 4 feet, and add the two. The run for 23 feet with a pitch of  $1/4$  is 25 feet 8  $5/12$  inches. For 4 feet, the run is 4 feet 5  $8/12$  inches. The total run for 27 feet is 30 feet 2  $1/2$  inches.

(6) The lengths that are given in the rafter table are line lengths. The overhang must be added.

(7) When the roof has an overhang, the rafter is usually cut square to save time. If the roof does not have an overhang, the rafter is cut plumb, but no notch is cut in the rafter seat.

(8) A level cut is made on the rafter long enough to extend across the plate and the wall sheathing. This type of rafter allows very little protection to the sidewalls.

**3-12. Template Use.** Rafter framing without the use of ridgeboards may be done rapidly by using a truss assembly jig or template. The template is laid out to form a pattern conforming to the exact exterior dimensions of the truss. Lay out a template as follows (see Figure 3-31).

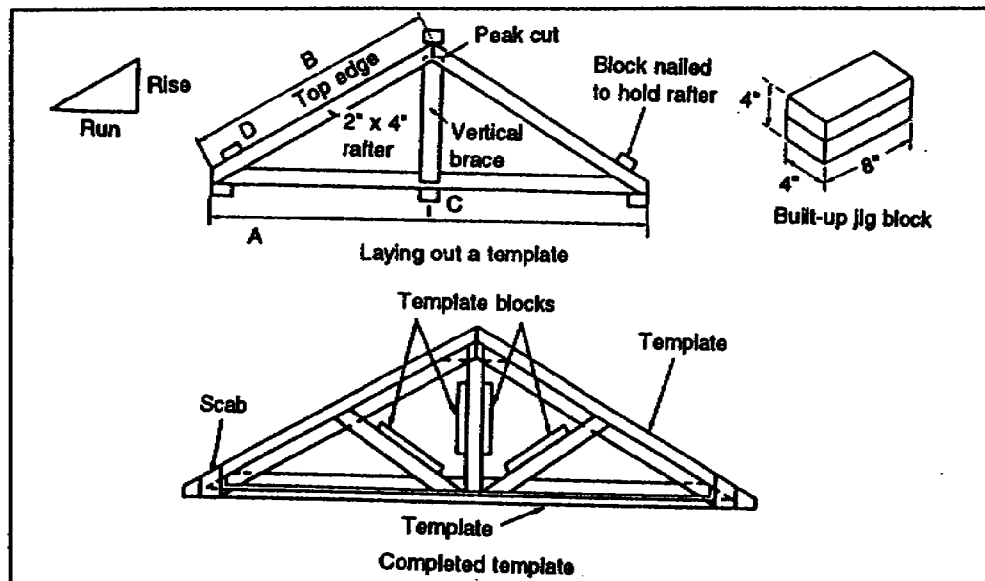


Figure 3-31. Laying out a template

a. Lay Out. Lay out a template as shown in Figure 3-31 and as follows:

(1) Measure and mark a straight line on a selected surface. Have the exact length of the joists that will form the truss chord. This is baseline A (see Figure 3-31).

(2) From the center of the baseline and at right angles to it lay out the centerline (C) to form the leg of a right triangle, the base of which is at half the length of baseline A, and the hypotenuse of which (B) is the length of the rafter measured as indicated (see Figure 3-31).

(3) Nail 2- by 4- by 8-inch blocks flush with the ends of baseline A and centerline C as shown in Figure 3-31. Mark the centerline on the center jig blocks.

b. Assembly. Assemble with a template as shown in Figure 3-31 and as follows:

- (1) Start the assembly by setting a rafter in the jig with the plate cut fitted over the jig block at one end of the baseline. The peak is flush with the centerline on the peak jig block. Nail a holding block outside the rafter at point D as shown in Figure 3-31.
- (2) Lay one 2- by 4-inch joist or chord in place across the base blocks.
- (3) Lay two 2- by 4-inch rafters in place over the joist.
- (4) Center one end of 1- by 6-inch hanger under the rafter peak. Center the rafters against the peak block.
- (5) Nail through the rafters into the hanger using six 8d nails.
- (6) Line up one end of the chord.
- (7) Nail through the rafter with 16d nails.
- (8) Line up the other end of the chord.
- (9) Nail as above.
- (10) Center the bottom of the hangers on top of the chord and nail with 8d nails.

**3-13. Roof Openings.** Major roof openings are those that interrupt the normal run of rafters or other roof framing. Such openings may be for ventilation, chimneys, trap-door passage, skylight, or dormer windows. Roof openings are framed by headers and trimmers. Double headers are used at right angles to the rafters, which are set into the headers in the same way as joists in floor-opening construction. Trimmers are actually double rafter construction in roof openings. Nailing steps may be added if needed. Figure 3-32 shows roof-opening construction.

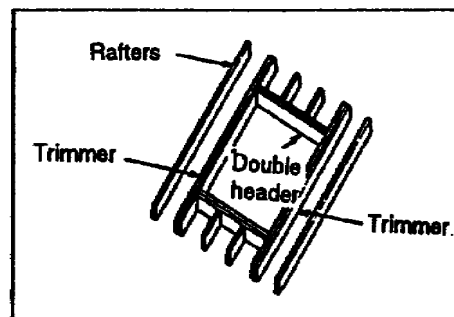


Figure 3-32. Roof opening

## PART C - ROOF-COVERING MATERIAL

Many different kinds of roof-covering materials are available, including tile, built-up roofing, asphalt shingles, mineral fiber (asbestos-cement) shingles, and wood shingles. Carpenters mainly work with the last three.

**3-14. Roof Sheathing.** Plywood or one-by material is satisfactory for sheathing roofs. Plywood is more economical than one-by material, and it can be installed rapidly. The thickness required is 3/8, 1/2, 5/8, or 3/4 inch depending on the rafter spacing, pitch, and load on the roof. When installing sheathing, be sure that the joints are placed over the rafters. The roof sheathing should be arranged so that the joints for the complete roof are staggered.

**3-15. Roof-Covering Terms.** These terms should be understood before proceeding with this part.

a. Square. Roofing is estimated and sold by the square. A square is the number of shingles required to cover 100 square feet of roof surfaces.

b. Coverage. Shingles overlap, and depending on the manner in which they are laid, one, two, or three thicknesses cover the roof at any one place. The roofing is termed single coverage, double coverage, and so on.

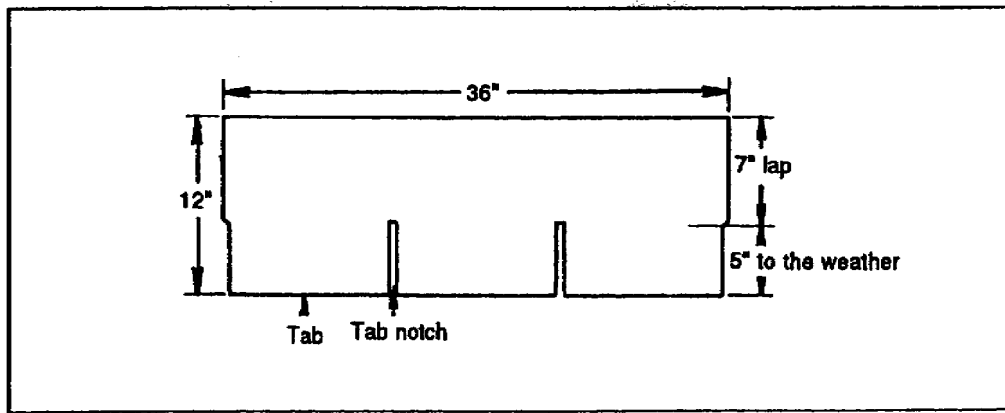
c. Shingle Butt. The shingle butt is the lower exposed edge of the shingle.

d. Exposure. The exposure is the distance from the butt of one shingle to the butt of the shingle above it. This is the portion of the shingle that is exposed to the weather.

e. Underlayment. The underlayment is the application of saturated felt that is placed over the roof surface to protect the roof sheathing until the shingles are applied.

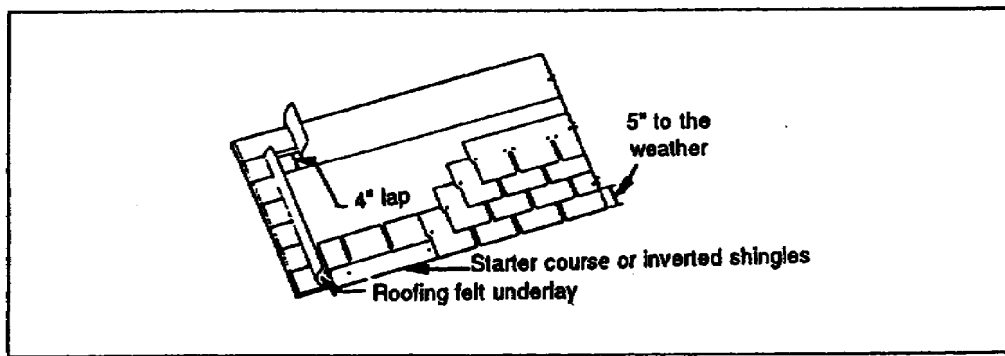
f. Toplap. The width of the shingles minus the exposure.

**3-16. Shingle Roof.** An asphalt-shingle roof begins with the application of a drip edge, followed by underlayment (felt) and eave flashing strips. Then, the first full shingle is inverted and nailed in place. Asphalt roofing comes in rolls (usually 3 feet wide), called *rolled roofing*; in rolled strips (usually 15 inches wide and 3 feet long); and as individual shingles. The type most commonly used is the flat strip, often called a *strip shingle*. The size of a square-butt strip shingle is 12 by 36 inches. This shingle should be laid 5 inches to the weather, meaning 7 inches of each course should be overlapped by the next higher course. There are various types of shingles. Figure 3-33 shows a butt shingle with three tabs.



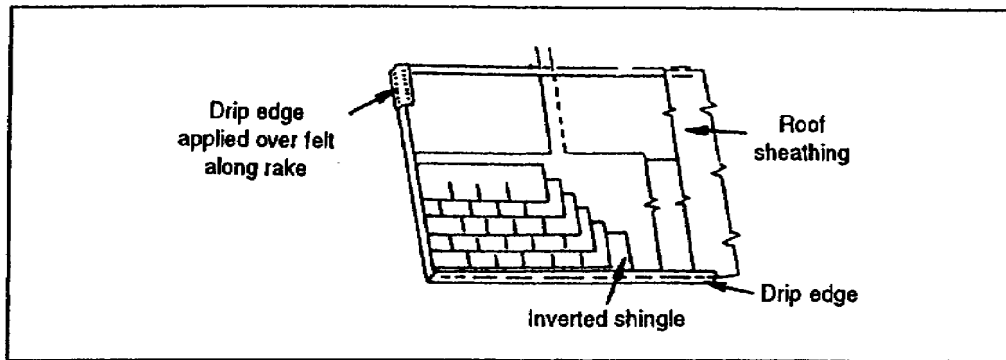
**Figure 3-33. Butt shingle**

**3-17. Shingle Installation.** The first step in covering a roof is to erect a scaffold to a height that will bring the eaves about waist-high to a man standing on the scaffold. Before any roof covering is applied, the roof sheathing must be swept clean and carefully inspected for irregularities, cracks, holes, or other defects. No roof should be applied unless the sheathing boards are absolutely dry. An underlay of roofing felt is first applied to the sheathing. Roofing felt usually comes in 3-foot-wide rolls and should be laid with a 2-inch top lap and a 4-inch side lap (see Figure 3-34). Bundles of shingles should be distributed along the scaffold before work begins. There are 27 strips in a bundle of 1 by 3 asphalt strip shingles. Three bundles will cover 100 square feet.



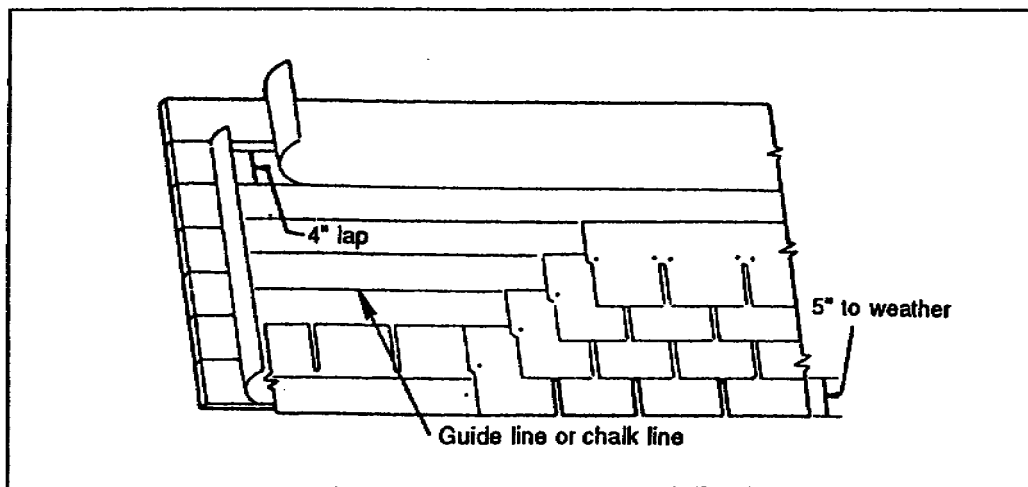
**Figure 3-34. Laying an asphalt shingle roof**

- a. Install the first course of shingles inverted. This arrangement provides a roofing edge without notches.
- b. Nail inverted shingles in place with 3/4-inch over the drip edge on the eaves and the gable ends of the roof (see Figure 3-35, page 3-28).



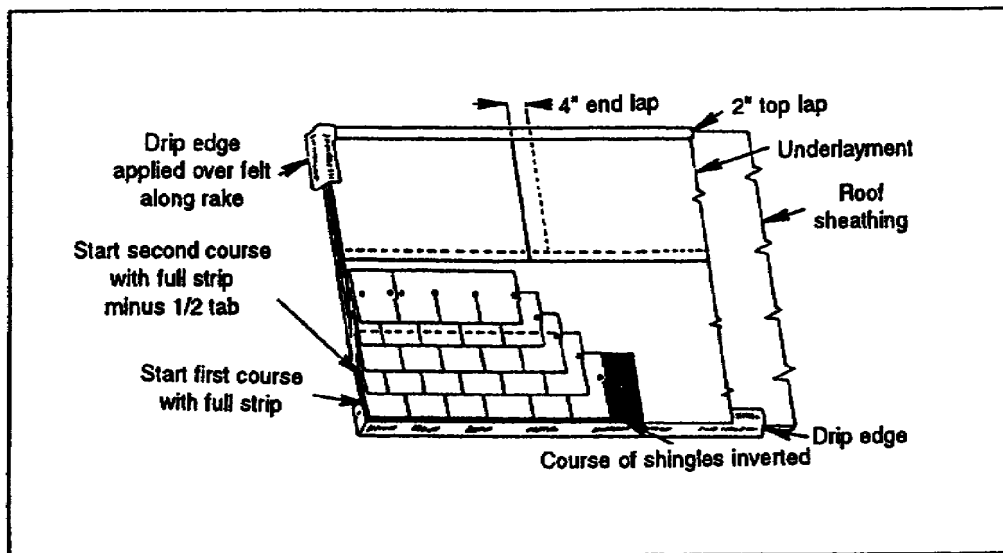
**Figure 3-35. Applying the drip edge**

- c. Snap chalk lines on the underlayment (felt) to indicate the location of each course (see Figure 3-36).



**Figure 3-36. Snapping a chalk line**

- d. Begin the first course of shingles with a whole strip at one end of the roof (see Figure 3-37).
- e. Cut the second course so that the lap occurs at the half-tab point (see Figure 3-37).
- f. Use four or six nails in each shingle.
- g. Use nails that are 1 1/4 inches long for new roofs.
- h. Place a nail 1 inch from the edge of the shingle.
- i. Place one or two nails near the tab slots (depending on the requirement) as shown in Figure 3-37.



**Figure 3-37. Laying the shingles**

- j. Passes each nail through two thicknesses of shingles and is concealed (blind nailed) by the next course of shingles.
- k. Finish the ridge of the roof by overlapping the shingles to prevent the roof from leaking.
- l. Make three short 12- by 12-inch shingles from a 12- by 36-inch shingle for the ridge of the roof
- m. Lay short shingles with an exposure of 5 inches to the weather.

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## LESSON 3

### PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer to each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

Situation. You are to construct a roof system. You know that the ceiling joists form the framework for the ceiling of a room.

1. Rafters make up the main body of the framework of all roofs. Rafters are extended a short distance beyond the wall to--
  - A. Strengthen the wall
  - B. Form the eaves and protect the sides of the building
  - C. Prevent the wind from passing between the top plate and the rafters
  - D. Strengthen the roof
2. What is the line length as used in roof framing?
  - A. The rise
  - B. The run
  - C. The span
  - D. The hypotenuse
3. What is the total run of an ordinary rafter?
  - A. Half of the span
  - B. Half of the run
  - C. The hypotenuse
  - D. The measurement of 12 inches
4. Common rafters extend from the \_\_\_\_\_ to the \_\_\_\_\_.
  - A. Plate to the hip rafter
  - B. Ridge to the valley rafter
  - C. Plate to the roof edge
  - D. Ridge to the roof edge

5. If a building is 20 feet wide, how many feet would the run of the rafter be?
- A. 25
  - B. 20
  - C. 15
  - D. 10
6. How is the first row of shingles installed?
- A. Horizontal
  - B. Up and down
  - C. Inverted
  - D. At an angle
7. Purlins are placed in the roof system to--
- A. Support the sheathing
  - B. Strengthen the top cord
  - C. Strengthen the bottom cord
  - D. Support the knee bracing
8. A roof is being covered with 12- by 36-inch strip shingles. How many inches of the shingles are left exposed to the weather?
- A. 5
  - B. 6
  - C. 7
  - D. 8
9. Ceiling joists are normally installed \_\_\_\_\_ inches on center?
- A. 16 or 24
  - B. 14 or 16
  - C. 12 or 14
  - D. 10 or 16

10. What does web members do?
- A. Forms a truss with two rafters
  - B. Divides a truss into triangles
  - C. Extends from the plate to the hip rafter
  - D. Forms the framework of the ceiling

## LESSON 3

### PRACTICE EXERCISE

#### ANSWER KEY AND FEEDBACK

<u>Item</u>	<u>Correct Answer and Feedback</u>
1. B	Form the eaves and protect the sides of the building They may extend . . . (page 3-4, para 3-6)
2. D	Hypotenuse In roof framing . . . (page 3-20, para 3-10e)
3. A	Half of the span Run always refers . . . (page 3-20, para 3-10i)
4. C	Plate to the roof edge These are framing . . . (page 3-5, para 3-6a(1))
5. D	10 Suppose the building . . . (page 3-8, para 3-6b(4))
6. C	Inverted Install the first . . . (page 3-27, para 3-17(a))
7. A	Support the sheathing Purlins are used . . . (page 3-17, para 3-8)
8. A	5 This shingle . . . (page 3-26, para 3-16)
9. A	16 Ceiling joists are usually . . . (page 3-3, para 3-5)
10. B	Divides a truss into triangles The web members . . . (page 3-14, para 3-7b)

## **APPENDIX A**

### **LIST OF COMMON ACRONYMS**

<b>•</b>	degree
<b>'</b>	foot, feet
<b>"</b>	inch, inches
<b>x</b>	by
<b>#</b>	number
<b>ACCP</b>	Army Correspondence Course Program
<b>AIPD</b>	Army Institute for Professional Development
<b>d</b>	penny
<b>DA</b>	Department of the Army
<b>DETC</b>	Distance Education and Training Council
<b>DOD</b>	Department of Defense
<b>FM</b>	field manual
<b>ft</b>	foot, feet
<b>ICE</b>	Interservice Correspondence Exchange
<b>lb</b>	pound(s)
<b>IPD</b>	Institute for Professional Development
<b>MOS</b>	military occupational specialty
<b>NHSC</b>	National Home Study Council
<b>No</b>	number
<b>RYE</b>	retirement year ending
<b>SSN</b>	social security number

**TM**            technical manual

**TRADOC**    US Army Training and Doctrine Command

## **APPENDIX B**

### **RECOMMENDED READING LIST**

The following publications provide additional information about the material in this subcourse. You do not need these materials to complete this subcourse.

FM 5-426. *Carpentry*. 3 October 1995.

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